MATERIALS BUREAU

TECHNICAL REPORT 92-2

MEMBRANE WATERPROOF APPLICATIONS IN NEW YORK

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MARIO M. CUOMO, Governor
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TECHNICAL REPORT 92-2

MEMBRANE WATERPROOFING APPLICATIONS IN NEW YORK

FINAL REPORT

Final Report on Experimental Feature Project 75-02, C-F
Conducted in Conjunction with
The U.S. Department of Transportation
Federal Highway Administration
National Experimental and Evaluation Program (NEEP) No. 12
Bridge Deck Protective Systems

Prepared by

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PREFACE

In 1976 five waterproofing membrane systems were installed with $2\frac{1}{2}$" thick asphalt overlays on concrete bridge decks in New York State. These membranes were installed to evaluate their effectiveness in concrete bridge deck rehabilitation work. The function of these membranes was to prevent the infiltration of water and salts into the concrete deck, thereby reducing corrosion of the reinforcing steel. Over a period of 13 years, these membranes were evaluated using electrical resistance readings, corrosion potential measurements, and visual observations. Of the five membranes evaluated, three were preformed sheet membranes and two were liquid membranes. All three of the preformed membranes and one of the liquid membranes were effective in preventing infiltration of water into the concrete deck. The other liquid membrane, a two-coat bituminous epoxy system, was permeable when first installed and consequently was considered ineffective as a waterproofing membrane.

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I. INTRODUCTION

A. Background

Bridge deck deterioration has been a long standing problem in New York. The major cause for deterioration is corrosion of the reinforcing steel from deicing salts. When bare reinforcing steel is placed in concrete a protective oxide forms which helps retard corrosion. The introduction of chloride ions from deicing salts however, disturbs the oxide and corrosion cells eventually form. One way of preventing or retarding the corrosion process is to prevent the infiltration of water and chloride ions. Waterproofing membranes overlaid with an asphalt wearing surface were proposed for this purpose.

B. Purpose and Scope

This study was conducted in conjunction with National Experimental and Evaluation Program (NEEP) No. 12, Bridge Deck Protective Systems. The purpose was to evaluate the performance of five membrane systems for use in bridge deck maintenance and repair work. The membranes evaluated were either preformed sheets or liquid systems and were placed as a waterproof barrier between a concrete deck and a $2\frac{1}{2}$" bituminous concrete overlay wearing surface.

This report is the final report of the study and evaluates the performance of the membranes after 13 years of service. Following are the membranes evaluated:

Membrane Name	Type
Heavy Duty Bituthene	preformed sheet
Royston Bridge Membrane No. 10	preformed sheet
Protecto-Wrap M400A	preformed sheet
NEA-4000LT	liquid
Bituminous Epoxy Membrane (two-coat application)	liquid

C. Previous Reports

Each of the five membrane systems was applied to a bridge deck and overlaid with a $2\frac{1}{2}$" thick bituminous concrete wearing course. To protect the preformed sheet membranes from being punctured by the aggregate in the overlay the maximum aggregate size used in the asphalt concrete mix was 3/8". There were no problems encountered during the installation of the membranes. Electrical resistance readings taken on the surface of the overlays revealed that all of the membranes, with the exception of the two-coat bituminous epoxy, were performing satisfactorily at the time of installation. The impermeability of the bituminous epoxy membrane was questionable because resistance readings were very low. A detailed description of the test areas, observations made during installation and specification requirements are included in the first interim report on this project, Technical Report 32, Membrane Applications in New York, dated April, 1977.

In 1977, resistance and potential readings were taken on each of the membrane installations. At that time, the membranes had been in service for approximately one year. Visual observations of the bridge decks and electrical resistance and potential tests indicated the three preformed sheet membranes and the NEA-4000LT liquid membrane were performing satisfactorily. The two-coat bituminous epoxy membrane, however, was permeable and ineffective as a waterproofing membrane material. Test data and a discussion of the membrane performance after one year of service can be found in the second interim report, Technical Report 34, Membrane Waterproofing Applications in New York, dated June, 1978.

II. CONSTRUCTION

A. Membrane Waterproofing Materials

Heavy Duty Bituthene

Heavy Duty Bituthene is a 65 mils (0.065 in.) thick preformed sheet membrane consisting of a woven polyethylene mesh coated on one side with a layer of rubberized asphalt. Since the start of this investigation the product name of this membrane has been changed to Bituthene waterproofing membrane 5000*. The Bituthene Primer and Bituthene Mastic used in the installation of this membrane have also had name changes. The primer is now Bituthene Primer P-3000 and the mastic is Bituthene Mastic EM-3000. All of these products are still manufactured by W.R. Grace and Company, Cambridge, MA.

Protecto-Wrap M-400A

Protecto-Wrap M-400A is a 70 ±5 mils (0.070 ±.005") thick preformed sheet laminate of aromatic tars, modified with synthetic resins, and reinforced with a synthetic non-woven fabric. Protecto-Wrap #80 Primer and 160H Mastic are used in the installation of the membrane. These materials are all manufactured by the Protecto-Wrap Co., Denver, CO.

Royston Bridge Membrane No. 10

Royston Bridge Membrane No. 10 is a 75 mils (0.075") thick preformed sheet consisting of a laminate of reinforced fiberglass mesh and bituminous mastic with a top surface of polyester film. Royston Bridge Membrane Primer 713 and Royston Roskote A-51 Black Mastic are used in the installation of the preformed sheet. All materials are manufactured by Royston Laboratories, Inc., Pittsburgh, PA.

NEA-4000 LT (Low Temperature)

NEA-4000LT is a liquid poly-vinyl chloride polymer waterproofing. It is hot applied with application temperatures from 275-300°F and is applied at a rate of approximately 18 sf/gal (90 mils). A sheet of 65 lb. roofing paper is a part of the system and is used as a protective layer to prevent damage during the bituminous

*For consistency with previous reports we will refer to this material by its previous name, Heavy Duty Bituthene, throughout this report.

overlay operations. Since the start of this investigation this product has undergone a name change and a manufacturer change. This material was formerly marketed on the east coast by POSH Chemical, Inc. of Port Washington, NY as NEA-4000LT. The material is now called NEA-BDW and is manufactured by KOCH Materials, Stroud, OK.**

Bituminous Epoxy (Two-Coat Application)

The bituminous epoxy membrane is a non-proprietary liquid waterproofing system. It is a two component, bituminous modified epoxy resin applied in two coats for a total thickness of approximately 100 mils. Stone aggregate is spread in the second coat to aid adhesion of the bituminous overlay.

B. Test Sites and Membrane Installation

General

To evaluate the five membrane systems, each system was installed on a separate bridge deck in 1976. Observations and measurements were made on each deck shortly after installation and again after various years of service. Final observations and measurements representing 13 years of service were made in 1989 on all but the NEA-4000LT membrane. The NEA-4000LT membrane was removed in 1988 when the bridge deck was rehabilitated.

Detailed information on the bridge sites and installations can be found in Technical Report 32, Membrane Waterproofing Applications in New York, Interim Report. The specifications used for the installations can be found in Appendices A-E. The following summarizes the membrane installations:

Heavy Duty Bituthene

Heavy Duty Bituthene was installed under Contract FARC 74-45, Corning Area Bridge Reconstruction, Federal Aid Project Number U-225(46). The bridge, BIN 1011209, is located approximately 2 miles west of the city of Corning, NY and carries US Rte. 15 (NY Rte. 17) over the Erie-Lackawanna Railroad. The bridge is a 3 span simple twin structure with an AADT of 20,900 and a grade of 0%. The Heavy Duty Bituthene was installed on the northbound lanes of spans 1 and 2 for a total of 21,785 sf.

Protecto-Wrap M-400A

Protecto-Wrap M400A was installed under Contract FARC 75-176, Waverly Area Bridge Rehabilitation, Federal Aid Project Number U-995(5). The bridge, BIN 1023170, is located approximately $1\frac{1}{4}$ miles north of the village of Waverly, NY and carries NY Rte. 34 over Cayuta Creek. The bridge is a through-girder single span, continuous structure with an AADT of 4,300 and a grade of 4%. The Protecto-Wrap M-400A was installed on the entire deck for a total of 5641 sf.

**For consistency with previous reports we will refer to this product by its previous name, NEA-4000LT, throughout this report.

Royston Bridge Membrane No. 10

Royston Bridge Membrane No. 10 was installed under Contract FARC 75-176, Waverly Area Bridge Rehabilitation, Federal Aid Project Number U-995(5). The bridge, BIN 1023180, is located approximately 1¼ miles north of the village of Waverly, NY and carries NY Rte. 34 over the Lehigh Valley Railroad. The bridge is a through-girder single span, continuous structure with an AADT of 4,300 and a grade of 0.5%. The Royston Bridge Membrane No. 10 was installed on the entire deck for a total of 3880 sf.

NEA 4000 LT (Low Temperature)

NEA-4000 LT liquid waterproofing membrane was installed under Contract FARC 75-45, Corning Area Bridge Reconstruction, Federal Aid Project Number U593(16). The bridge, BIN 1011160, is located at Painted Post, NY, approximately 1 mile west of the city of Corning. The structure is a simple 8 span bridge which carries US Rte. 15 over the Cohocton River, has an AADT of 23,600 and a grade of 0%. The NEA-4000LT liquid waterproofing membrane was installed on Spans 2 and 5 for a total of 30,292 sf.

Bituminous Epoxy (Two-Coat Application)

The bituminous epoxy liquid waterproofing membrane was installed under Contract M75-3, Rehabilitation of the Delaware Avenue Bridge. The bridge, BIN 4453030, is located in the cities of Tonawanda and North Tonawanda, NY and carries Delaware Avenue over the Erie Canal. The bridge is a 3 span simple truss structure with an AADT of 10,600 and grades of 0% on Span A, 3% on Span B and 5.5% on Span C. The bituminous epoxy membrane was installed on Spans A and B for a total of 8000 SF. The membrane was not installed on Span C because of its steep grade. This section was used as a control section.

C. Cost

The 1976 installation cost for all of the membranes with the exception of the bituminous epoxy was $4.50/sy. The cost of the bituminous epoxy was $23.85/sy. These costs include all materials, equipment and labor necessary to place the waterproofing membrane, but do not include the cost of the 2½" thick bituminous overlay.

III. PERFORMANCE

A. Criteria

The performance of the waterproofing systems was determined on the basis of three surveys performed after 1, 8, and 13 years of service. Each of the surveys consisted of the following observations and measurements:

1. Visual Observations: to locate cracks, areas of water seepage and other types of visible distress.

2. Electrical Resistance: electrical resistance measurements were taken on a five foot by five foot coordinate grid to assess the water impermeability of the membrane system. The test method consisted of measuring the electrical resistance between an electrode placed on the surface of the deck and the top mat of reinforcing steel in the deck. The results are interpreted as follows:

Electrical Resistance Value	Membrane Performance
>500 kil-ohm-sf	acceptable
<100 kil-ohm-sf	unacceptable
100-500 kil-ohm-sf	inconclusive

When interpreting the results it should be noted that measurements made through a bituminous wearing surface may introduce an error due to the electrical resistance of the wearing surface. If an error is introduced the results will indicate a higher resistance value and therefore better membrane performance than actually exists. The error has been estimated at 0.9% at 100 kil-ohm-sf, 4.5% at 500 kil-ohm-sf and 58.0% at 6400 kil-ohm-sf. Data in this report has not been corrected for this error[1].

3. Corrosion Potential: corrosion potential measurements were taken on a five foot by five foot coordinate grid using a copper-copper sulphate half cell reference electrode. This test method can be used on exposed concrete slabs to define areas of reinforcing bar corrosion activity.

Measurements are interpreted are as follows:

1. Potentials more positive than -0.20V indicate that no reinforcing steel corrosion is occurring.

2. Potentials in the range of -0.20 to -0.35V provide no definite information on corrosion activity.

3. Potentials more negative than -0.35V indicate that reinforcing steel corrosion is occurring.

From past test data, high electrical resistance measurements (>500 kil-ohms-sf) have usually coincided with low corrosion potentials (more positive than -.20V). These results are to be expected especially when one considers that corrosion potential measurements involve establishment of an electrical circuit with the reinforcing steel. When corrosion potential is measured on an impervious membrane the circuit is interrupted by the membrane. The result is a low corrosion potential value. Measurements taken on NYSDOT structures have shown that electrical resistance values approaching infinity are associated with corrosion potentials near zero. It's only when the membrane becomes extensively damaged to the point where a circuit is easily established that an accurate corrosion potential can be recorded. If only a few holes are made in the membrane the circuit is only partially established. The membrane in this situation still has a high enough resistance to prevent an accurate potential measurement. Potential measurements therefore remain low.

Based on the above observations the corrosion potential tests were interpreted as follows:

1. A corrosion potential of <0.20V is indicative of acceptable membrane performance; but not necessarily an indication of low reinforcing bar corrosion activity.

2. A corrosion potential of >0.35V is indicative of unacceptable membrane performance and a probable indication that active corrosion of the reinforcing steel is occurring.

3. The range of corrosion potential values between 0.20V to 0.35V is undefined, in regard to membrane performance and corrosion activity.

B. Observations and Data

Evaluation of the five membrane systems began in 1977 after each had been in service for one year. From 1977 to 1984 most of the installations were evaluated annually. A final evaluation was performed in 1989. The evaluation of each system consisted of conducting a visual survey of the installation and taking resistance and corrosion potential measurements. A discussion of the results for each membrane system follows.

Electrical resistance and corrosion potential measurements for each installation are in Table 1. Resistance data in each interval is given as a percentage of the total number of measurements taken. A statistical analysis of the resistance data was not performed because when the infinity values are combined with the values below 100 kil-ohms-sf the results are meaningless. Figure 1 graphs the percentage of acceptable resistance readings from Table 1 versus the years of service. This graph compares the performance of the five membranes. Along with the data in Table 1 the resistance and corrosion potential data are shown on contour maps. The initial 1977 data, 1984 data and the final 1989 data for each installation can be found on these maps. The maps display deck areas having electrical resistance values in one of three ranges: <100, 100 to 500, >500 kil-ohms-sf. The corrosion potential maps display areas having potentials of <-0.20V, -0.20 to -0.35V, or >-0.35V.

TABLE 1 - ELECTRICAL RESISTANCE AND CORROSION POTENTIAL TESTING

MEMBRANE SYSTEM	Survey Years	Years In-Service	ELECTRICAL RESISTANCE				CORROSION POTENTIAL							
				Percentages								Percentages		
			No. Meas. (n)	>500K	500 to 100K	<100K	No. Meas. (n)	Mean (volts)	Std. Dev.	Min. (volts)	Max. (volts)	<.20V	.20-.35V	>.35V
Heavy Duty Bituthene	1976	0	45	98	2	0	*	*	*	*	*	*	*	*
Span 1	1977	1	125	83	6	11	123	0.16	0.13	0.00	0.44	57	36	7
	1978[1]	2	93	74	10	16	87	0.15	0.14	0.00	0.44	60	30	10
	1979	3	124	68	11	21	124	0.19	0.14	0.00	0.47	52	35	13
	1980	4	125	61	11	28	125	0.18	0.16	0.00	0.54	55	27	18
	1981	5	125	62	23	15	125	0.16	0.14	0.01	0.49	66	20	14
	1982[2]	6	113	57	12	31	83	0.18	0.14	0.01	0.47	69	13	18
	1983	7	125	61	9	30	125	0.16	0.14	0.01	0.50	66	21	13
	1984	8	125	59	8	33	125	0.18	0.15	0.00	0.49	63	20	17
	1989	13	125	60	3	37	125	0.22	0.18	0.01	0.63	54	16	30
Span 2	1976	0	61	90	8	2	*	*	*	*	*	*	*	*
	1977	1	198	82	11	7	198	0.10	0.12	0.00	0.48	79	16	5
	1978	2	197	72	14	14	196	0.13	0.13	0.00	0.58	73	21	6
	1979	3	198	74	12	14	198	0.13	0.15	0.00	0.48	71	18	11
	1980	4	197	72	11	17	196	0.13	0.16	0.00	0.70	72	16	12
	1981	5	198	72	14	14	198	0.12	0.13	0.00	0.51	75	17	8
	1982[2]	6	198	71	10	19	132	0.15	0.14	0.00	0.60	70	18	12
	1983	7	198	70	3	27	198	0.13	0.13	0.00	0.49	73	16	11
	1984	8	199	68	6	26	198	0.13	0.13	0.01	0.49	73	19	8
	1989	13	194	61	7	32	194	0.16	0.15	0.00	0.47	66	10	24

[1] Random points selected because of time constraint.

[2] Potentials not taken in passing lane due to misplacement of equipment.

*Corrosion potential testing on paved membrane was not performed in 1976 survey.

TABLE 1 - ELECTRICAL RESISTANCE AND CORROSION POTENTIAL TESTING

MEMBRANE SYSTEM	Survey Years	Years In-Service	ELECTRICAL RESISTANCE				CORROSION POTENTIAL							
			No. Meas. (n)	Percentages			No. Meas. (n)	Mean (volts)	Std. Dev.	Min. (volts)	Max. (volts)	Percentages		
				>500K	500 to 100K	<100K						<.20V	.20-.35V	>.35V
Protecto-Wrap M-400A	1976	0	80	99	1	0	*	*	*	*	*	*	*	*
	1977	1	263	92	4	4	263	0.09	0.10	0.00	0.41	77	22	1
	1978	2	262	87	6	7	262	0.12	0.10	0.00	0.40	75	24	1
	1979	3	262	88	7	5	262	0.08	0.10	0.00	0.46	85	13	2
	1980	4	262	81	9	10	262	0.09	0.12	0.00	0.62	80	18	2
	1981[3]	5	260	80	13	7	236	0.14	0.12	0.00	0.61	72	22	6
	1982	6	261	56	23	21	261	0.16	0.11	0.01	0.49	63	36	1
	1984	8	261	54	14	32	261	0.17	0.14	0.00	0.47	53	37	10
	1989	13	254	33	7	60	254	0.25	0.17	0.01	0.55	45	18	37
Royston-Bridge Memb. No. 10	1976	0	60	92	7	1	*	*	*	*	*	*	*	*
	1977	1	180	76	16	8	180	0.18	0.11	0.00	0.39	45	52	3
	1978	2	180	66	20	14	180	0.16	0.10	0.00	0.38	47	51	2
	1979	3	180	77	8	15	180	0.13	0.09	0.00	0.37	80	19	1
	1980	4	180	67	11	22	180	0.16	0.10	0.00	0.47	73	23	4
	1981	5	180	44	12	44	180	0.20	0.11	0.01	0.44	55	37	8
	1982	6	180	43	13	44	180	0.17	0.12	0.01	0.40	60	34	6
	1984	8	180	37	16	47	180	0.23	0.12	0.01	0.47	38	41	21
	1989	13	180	19	8	73	180	0.33	0.14	0.01	0.56	15	34	51

[3] Readings not completed due to rain.

*Corrosion potential testing on paved membrane was not performed in 1976 survey.

TABLE 1 - ELECTRICAL RESISTANCE AND CORROSION POTENTIAL TESTING

MEMBRANE SYSTEM	Survey Years	Years In-Service	ELECTRICAL RESISTANCE				CORROSION POTENTIAL							
			No. Meas. (n)	Percentages			No. Meas. (n)	Mean (volts)	Std. Dev.	Min. (volts)	Max. (volts)	Percentages		
				>500K	500 to 100K	<100K						<.20V	.20-.35V	>.35V
Nea-4000 LT														
Span 2	1976	0	62	97	2	1	*	*	*	*	*	*	*	*
	1977	1	70	86	8	6	70	0.12	0.15	0.00	0.68	70	24	6
	1978	2	71	87	0	13	71	0.08	0.12	0.00	0.61	80	17	3
	1979	3	71	86	1	13	71	0.07	0.12	0.00	0.49	80	16	4
	1980	4	72	89	7	4	72	0.07	0.12	0.00	0.63	87	10	3
	1981	5	70	87	3	10	70	0.13	0.10	0.03	0.60	79	17	4
	1982	6	72	85	7	8	72	0.07	0.12	0.00	0.62	92	5	3
	1983	7	72	89	1	10	72	0.04	0.08	0.00	0.42	94	4	2
	1984	8	72	88	4	8	72	0.11	0.07	0.01	0.28	89	11	0
	1989	13	**	**	**	**	**	**	**	**	**	**	**	**
Span 5	1976	0	65	97	3	0	*	*	*	*	*	*	*	*
	1977	1	70	80	4	16	70	0.14	0.18	0.00	0.71	63	27	10
	1978	2	72	93	4	3	72	0.12	0.14	0.01	0.60	71	22	7
	1979	3	71	91	0	9	71	0.07	0.12	0.00	0.54	83	14	3
	1980	4	68	90	3	7	68	0.04	0.07	0.00	0.28	93	7	0
	1981	5	73	85	8	7	73	0.10	0.08	0.01	0.32	86	14	0
	1982	6	72	88	4	8	72	0.09	0.11	0.01	0.57	89	7	4
	1983	7	72	85	4	11	72	0.05	0.08	0.01	0.48	94	4	2
	1984	8	72	89	0	11	72	0.12	0.09	0.01	0.47	87	10	3
	1989	13	**	**	**	**	**	**	**	**	**	**	**	**

*Corrision potential testing on paved membrane was not performed in 1976 survey.
**Data could not be collected during 1989 survey because bridge deck had been rehabilitated in 1988.

TABLE 1 - ELECTRICAL RESISTANCE AND CORROSION POTENTIAL TESTING

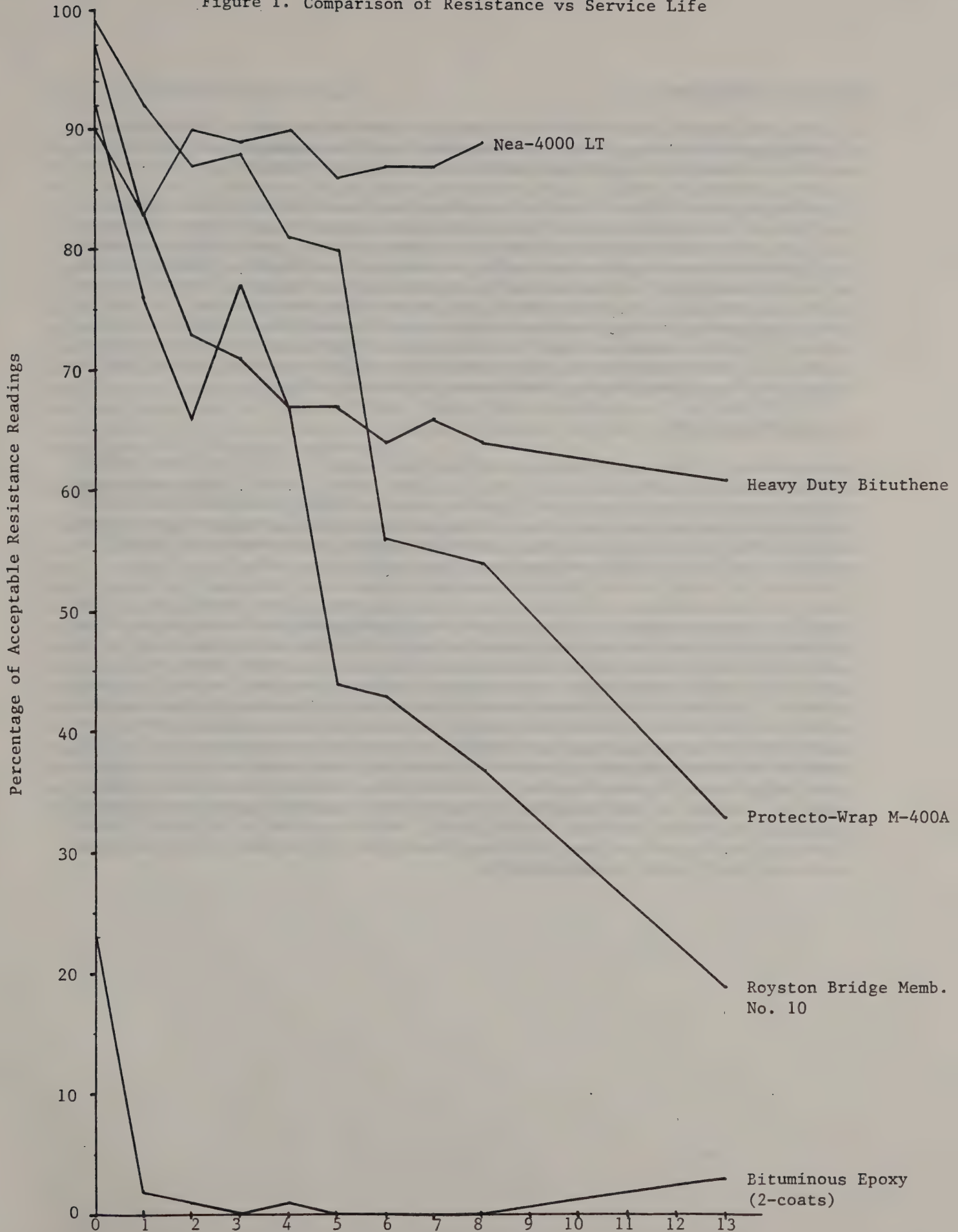
MEMBRANE SYSTEM	Survey Years	Years In-Service	ELECTRICAL RESISTANCE				CORROSION POTENTIAL							
			No. Meas. (n)	Percentages			No. Meas. (n)	Mean (volts)	Std. Dev.	Min. (volts)	Max. (volts)	Percentages		
				>500K	500 to 100K	<100K						<.20V	.20-.35V	>.35V
Bituminous Epoxy (2-coats)														
Span A	1976	0	20	30	30	40	*	*	*	*	*	*	*	*
	1977	1	153	3	11	86	153	0.28	0.07	0.12	0.48	8	79	13
	1978	2	151	1	1	98	144	0.28	0.07	0.11	0.46	8	79	13
	1979[3]	3	81	0	0	100	81	0.21	0.11	0.00	0.42	46	41	13
	1980	4	153	0	0	100	153	0.27	0.09	0.05	0.55	17	67	16
	1981	5	153	0	1	99	153	0.27	0.09	0.05	0.55	23	60	17
	1984[3]	8	68	0	1	99	68	0.25	0.08	0.11	0.42	28	59	13
	1989	13	153	5	9	86	153	0.25	0.09	0.06	0.47	29	60	11
Span B	1976	0	20	15	30	55	*	*	*	*	*	*	*	*
	1977	1	207	0	1	99	207	0.22	0.07	0.08	0.44	48	48	4
	1978	2	207	0	0	100	205	0.21	0.08	0.05	0.44	50	46	4
	1979[3]	3	115	0	0	100	110	0.14	0.12	0.00	0.60	69	27	4
	1980	4	207	1	1	98	207	0.21	0.08	0.04	0.45	54	38	7
	1981	5	207	0	2	98	207	0.21	0.09	0.02	0.44	51	42	7
	1984[3]	8	43	0	0	100	40	0.23	0.10	0.05	0.39	35	57	8
	1989	13	207	0	1	99	207	0.20	0.10	0.00	0.48	53	42	5
Span C[4]	1976	0	20	20	30	50	*	*	*	*	*	*	*	*
	1977	1	207	2	4	94	207	0.32	0.09	0.02	0.62	7	60	33
	1978	2	207	3	8	89	207	0.30	0.10	0.11	0.60	15	55	30
	1979[3]	3	113	2	4	94	113	0.30	0.12	0.01	0.63	19	47	34
	1980	4	207	3	8	88	207	0.29	0.12	0.07	0.63	28	39	33
	1981	5	207	1	7	92	207	0.29	0.13	0.05	0.64	30	36	34
	1984[3]	8	92	0	0	100	92	0.26	0.13	0.06	0.52	39	37	24
	1989	13	207	1	0	99	207	0.31	0.14	0.04	0.58	27	30	43

[3] Readings not completed due to rain.

[4] No waterproofing membrane treatment.

*Corrosion potential testing on paved membrane was not performed in 1976 survey.

Figure 1. Comparison of Resistance vs Service Life



Heavy Duty Bituthene

The Heavy Duty Bituthene membrane system was installed on two northbound spans of a bridge near Corning, NY. The heavy duty bituthene membrane performed well over the evaluation period with a gradual decrease in performance over time.

Resistance measurements from Table 1 show a gradual decrease in acceptable readings, (>500 kil-ohms-sf), while the mean potential values are fairly consistent at -.13 to -.16V. After 13 years of service the percentages of acceptable resistance readings and acceptable potential readings were approximately 60%. The only visual defects that developed were a crack at the longutudinal joint between the driving lane and the passing lane, and a depressed joint between the ramp lane and the driving lane. Resistance readings taken at these locations were low, (100 kil-ohms-sf), indicating that the membrane had been damaged. The resistance contour maps in Appendix A show these areas of low resistance along the longitudinal paving joints. Overall the Heavy Duty Bituthene membrane performed acceptably.

Protecto Wrap M-400A

Protecto Wrap M-400A was installed on a bridge near Waverly, NY. The Protecto Wrap M-400A membrane performed well for the first five years, over 80% of the resistance readings were acceptable and over 72% of the potential readings were less than .20V. After six years of service however only 56% of the resistance readings were acceptable and 63% of the potential readings were less than .20V. Contour maps displaying the data from the 1984 and 1989 evaluations can be found in Appendix B.

Although the membrane was performing well one year after installation visual distresses were noted in the overlay. A crack occurred along the entire length of the longitudinal construction joint and the asphalt slipped in the downhill direction in the northbound lane. Both distresses were considered minor. Cracks from outgassing between the 15 ft. and 20 ft. transverse grid points, however, were of greater concern. Outgassing is the formation of gases under the membrane which cause a bubble to form, cracking the asphalt overlay. When resistance readings were taken over these cracks the readings were >1000 kil-ohms-sf which is acceptable. In 1979, however, additional outgassing was noted, and when these areas were tested with a chain drag the overlay was found to be delaminated. In the end, outgassing caused premature failure of the membrane. Failure was indicated by a large drop in acceptable resistance readings, from 80% to 56%, which occurred in 1982 after 6 years of service, see Figure 1. Although the membrane failed, the asphalt overlay remained intact over the 13 year evaluation period.

Royston Bridge Membrane No. 10

The Royston Bridge Membrane No. 10 was also installed on a bridge deck near Waverly, NY. The Royston membrane performed well in the southbound lane of the bridge for six years until 1982, when cracks from outgassing were noted. On the otherhand, the northbound lane didn't perform as well. Deterioration was noted between the 15 ft and 20 ft transverse grid points as early as 1977, one year after installation. Deterioration consisted of numerous cracks and delaminations, probably due to outgassing. Random resistance readings taken in the cracked areas were <100 kil-ohms-sf indicating failure of the membrane. The contour maps found in Appendix C show the low resistance readings in the northbound lane. The percentages of acceptable resistance readings in Table 1 and Figure 1 don't differentiate between northbound or southbound lanes. They do, however, show large drops in acceptable resistance readings for the bridge deck as a whole. These drops occurred in 1977 and 1981, which is approximately when the distresses were noted in the northbound and southbound lanes, respectively. The Royston Bridge Membrane No. 10 did not perform as well as the Protecto-Wrap, Heavy Duty Bituthene or the NEA-4000 LT membranes. It appears that the Royston membrane had more of a problem with outgassing than the other membranes.

NEA-4000LT (Low Temperature)

The liquid NEA-4000LT membrane was installed on two southbound lanes of a bridge near Corning, NY. The NEA-4000LT membrane performed well. The only visual defects that appeared were a longitudinal crack at the construction joint (15 ft transverse grid position) and a small area near the curb line on Span 5 where the asphalt had shoved. With the exception of the resistance readings taken at the construction joint (<100 kil-ohms-sf), the readings were consistently high. The percentage of acceptable readings decreased only slightly over the 8 years it was evaluated. In 1976, 97% of the resistance readings were acceptable and in 1989, 88% were acceptable. Correspondingly, the potential readings were low over the evaluation period with 70 -94% of the potential readings being less than .20V. Contour maps in Appendix D show the resistance and potential test results taken in 1984. The resistance contour maps clearly show low resistance readings at the construction joint and high resistance readings for the rest of the deck. Likewise, the potential contour maps show areas of indeterminant corrosion activity along portions of the construction joint and potential readings less than .20V over most of the deck.

Bituminous Epoxy (two-coats)

A two-coat bituminous epoxy membrane was installed on two spans of a three span structure located between the cities of Tonawanda and N. Tonawanda, NY. The epoxy membrane was installed on Spans A and B of the structure. Because it had a steep grade of 5½%, Span C was not treated with the epoxy membrane and was used as a control section.

The bituminous epoxy membrane didn't performed well. The contour maps in Appendix E show the low resistance readings on the bituminous epoxy treated spans. Resistance readings taken after installation indicated that only 30% of the readings were acceptable on Span A and only 15% of the readings were acceptable on Span B. As for Span C, the span with no membrane, 20% of the resistance readings were acceptable. The untreated span was performing as well as the treated spans, which meant that the bituminous epoxy membrane was of little or no use. Acceptable resistance readings on the treated spans eventually decreased to zero. Potential readings on these spans didn't follow the expected pattern of low resistance readings being accompanied by high potential readings. The results on Spans A and C somewhat follow the expected pattern with the majority of the potential readings being greater than .20V when the resistance readings were low. The majority of the potential readings on Span B however are less than .35V. The depth of the concrete over the top reinforcing mat on the structure is 2½-3" which is the most cover of any of the five experimental decks. This might explain why the potential readings weren't as high as expected. It doesn't, however, explain why Spans A and C had higher potential readings than Span B. The consistently low resistance readings for all three spans indicate that the membrane was not performing as intended.

Another performance problem with the bituminous epoxy membrane was poor adhesion of the asphalt overlay. The 1978 evaluation, performed after two years of service life, revealed that a 20 ft x 10 ft section of asphalt in the southbound lane of Span A had shoved and was separating from the epoxy membrane. This area was located approximately 300 ft before a traffic signal and was subject to automobile breaking action. Other visual defects noted during the evaluation period were spalls at the headers, cracks, ravelling and a pot hole.

C. Findings

Based on the results of this study, the NEA-4000LT membrane out-performed the other systems. The NEA-4000LT system maintained the highest percentage of acceptable resistance readings (97-88%) during eight years of service. Unfortunately, the NEA-4000LT test deck was rehabilitated in 1988 so its performance after 13 years could not be determined. The other liquid membrane system, the two-coat bituminous epoxy membrane, didn't perform well at all. The spans treated with this system, Spans A and B, performed no better than the untreated span, Span C.

Of the three preformed membrane systems, the Heavy Duty Bituthene performed the best with 60% of the resistance readings being acceptable after 13 years of service. Both the Protecto-Wrap and the Royston membranes had a marked decrease in acceptable resistance readings after 5 and 4 years of service respectively. Both systems also had cracking in the overlay due to outgassing. In spite of the loss of impermeability both of the overlays on these systems performed fairly well from a maintenance standpoint. The visual distresses in the overlays were not major ones that required repairs.

One distress was common to all of the membrane systems. Soon after construction, each of the systems developed cracks along the longitudinal paving joints. Eventually, the resistance readings taken over these cracks became low and unacceptable, <100 kil-ohms-sf.

IV. SUMMARY

A. Conclusions

This study was initiated to determine whether or not five different waterproof membrane materials would prevent or retard corrosion of bridge deck reinforcing steel. Visual observations, electrical resistance testing and corrosion potential testing were used successfully to determine the permeability of membranes. Without control decks, it was not possible to determine whether or not corrosion of the deck reinforcement was retarded. High electrical resistance readings corroborate the fact that water was not infiltrating the membrane. Corrosion potentials, while an indicator of corrosion activity, are not reliable in areas of high resistance readings and therefore should not be used as a deciding factor in overall membrane performance. The deciding factor should be the actual service life in the field[2]. This study suggests the three preformed membranes and the NEA-4000LT have an average service life of approximately 8 years which is close to the service life of a $2\frac{1}{2}$" asphalt overlay. By preventing the infiltration of water and chlorides into the concrete deck these membranes retard deterioration of the concrete. The asphalt overlay will be essentially maintenance free for the service life of the membrane.

B. Recommendations

The results of this evaluation lead to the following recommendations:

1. The Heavy Duty Bituthene, Protecto Wrap M-400A, Royston Bridge Membrane No. 10 and NEA-4000LT membranes should continue to be used as waterproofing membranes for structural bridge decks.

2. The two-coat bituminous epoxy membrane should not be used as a waterproofing membrane.

3. The cracks forming along the longitudinal paving joints should be sealed to prevent premature failure of the waterproof membrane.

C. Current Practice

Initially, waterproofing membranes were used only in new construction. At that time bridge decks were designed to have a waterproofing membrane with a bituminous asphalt overlay. Over the years, NYSDOT policy has changed and today membranes are used only in rehabilitation work. For new construction or complete deck replacement, the current practice is to construct the structural deck and wearing surface monolithically, using epoxy coated reinforcing bars in the top mat. Today waterproofing membranes have a special place in bridge deck rehabilitation. For maintenance work forces operating on small budgets, waterproofing membranes offer a fast inexpensive method for prolonging the life of a bridge deck. Many maintenance forces use waterproof membranes as a stopgap until funds are available to replace the deck.

The installated cost of waterproofing membranes has varied over the years. Since 1986, however, the weighted-average-cost has been $17.37 per sy. In 1990, Standard Specification 717-02 Bituminous Epoxy Protective Coating (two-coat bituminous epoxy membrane) was removed from NYSDOT Standard Specifications because this study found it did not prevent the infiltration of water. As a result, no current cost data for the bituminous epoxy membrane is available.

The installation cost is not the only item that has changed. The Department's specifications have also changed. The current specification was adopted in 1977. The specification, Item 15558.50 Membrane Waterproofing System for Structural Slabs, includes the three preformed membranes evaluated in this study and three liquid membranes. These liquid membranes are high temperature (HT) versions of the NEA-4000LT that was evaluated in this study. One of the liquid membranes is no longer available, the Watson-Bowman HT Liquid System. Due to this change and the name and supplier changes mentioned previously the specification will be revised in the near future.

V. ACKNOWLEDGEMENTS

Acknowledgement is greatfully made to the many people within New York State Department of Transportation who have been involved with the construction and evaluation of the subject waterproofing membranes. The following people should receive special mention for their contribution to this report:

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Harry Sloan, Materials Bureau - Data Collection and Evaluation
David Brewster, Materials Bureau - Data Collection and Evaluation
Joseph Micare, Materials Bureau - Graphics
Eileen Frederick, Materials Bureau - Typing
Denise DeVito, Materials Bureau - Typing

VI. REFERENCES

1. Chamberlin, W. P., Irwin, R. J., and Amsler, D. E. Waterproofing Membranes for Bridge Deck Rehabilitation. Research Report 52, Engineering Research and Development Bureau, New York State Department of Transportation, May 1977.

2. Manning, D. G., and Ryell, J. "Decision Criteria for the Rehabilitation of Concrete Bridge Decks". Transportation Research Record 762, Transportation Research Board, 1980, pp. 1-9.

VII. APPENDICES

A. Heavy Duty Bituthene Membrane Waterproofing

   1. Specification
   2. Electrical Resistance Contour Maps
   3. Potential Contour Maps

B. Protecto-Wrap M-400A Membrane Waterproofing

   1. Specification
   2. Electrical Resistance Contour Maps
   3. Potential Contour Maps

C. Royston Bridge Membrane No. 10

   1. Specification
   2. Electrical Resistance Contour Maps
   3. Potential Contour Maps

D. NEA-4000 LT Membrane Waterproofing

1. Specification
2. Electrical Resistance Contour Maps
3. Potential Contour Maps

E. Bituminous Epoxy Membrane Waterproofing (Two-Coat Application)

1. Specifications
2. Electrical Resistance Contour Maps
3. Potential Contour Maps

APPENDIX A

Heavy Duty Bituthene Membrane Waterproofing

ITEM BRIDGE PREFORMED MEMBRANE WATERPROOFING SYSTEM (HEAVY DUTY BITUTHENE)

SCOPE:

The work shall consist of furnishing and applying a preformed membrane waterproofing system. It shall include, but not be limited to the preparation of concrete surfaces; the application of cold applied primer and preformed membrane as specified in the Contract Documents.

MATERIALS:

The preformed membrane waterproofing system shall be as manufactured by W. R. Grace & Company, Cambridge, Massachusetts, and shall consist of the following materials:

Bridge Preformed Membrane - Heavy Duty Bituthene

Primer - Bituthene Primer

Mastic Sealer - Bituthene Mastic

Wire mesh, for use over subdrainage openings, shall be a first class, 1/4-inch mesh by 23 gauge, hot-dipped galvanized cloth.

CONSTRUCTION DETAILS:

A. Preparation of Structural Slab Surfaces.

All structural slab surfaces that are to be waterproofed, including vertical surfaces, shall be prepared and cleaned as follows: Unless otherwise directed by the Engineer, work shall not begin on new structural slabs until a minimum of 28 days after concrete placement.

1. All loose material, including dirt, stones, gravel and concrete laitance shall be removed by vacuuming or blowing with compressed air.

2. Any excess laitance (surface film of concrete), road oil, other bituminous based contaminates, and other foreign materials, including concrete curing compounds, which are detrimental to membrane adhesion shall be removed by sandblasting or wire brushing and washing with water or a combination of these methods. To determine if adhesion problems exist, small test patches of primer and membrane, shall be applied to the area(s) in question. These test patches shall then be checked by the Engineer to determine the compatibility and adhesion of the membrane to the concrete surface.

3. All surface projections, including exposed aggregate or any other conditions which have presented so rough a concrete surface, as determined by the Engineer to be detrimental to the membrane, shall be ground smooth, or grouted smooth with cement mortar or epoxy. If grouting materials are used, they shall be "set up" and

surface dry, prior to application of primer. Cement mortar mixes for use in grouting shall be approved by the Engineer prior to use. Epoxy mortar materials shall consist of epoxy material meeting the requirements of Material Specifications 721-01, 721-02 or 721-03, and fine aggregate as approved by the Engineer.

4. Immediately prior to primer application, surfaces to be primed shall be re-cleaned of dust and other loose foreign material by vacuuming or blowing with compressed air.

B. Atmospheric Conditions.

Work shall not be done during wet weather conditions, nor when determined by the Engineer atmospheric conditions are such as to produce unsatisfactory results. No work shall be done when the structural slab surface temperature is below 40°F and ambient temperatures are below 40°F. The concrete structural slab shall be surface dry at the time of primer application.

C. Primer Application.

After cleaning, all concrete surfaces to be waterproofed shall be primed with Bituthene Primer. The primer shall be thoroughly mixed prior to use. Mixing shall be done with mechanical mixers or hand mixed, using clean paddles or other suitable instruments. All settled material shall be thoroughly dispersed.

The primer shall be applied, without dilution, by the use of brushes or rollers or a combination of these methods. Spray application of primer will not be allowed. The primer shall be applied at the rate of 200-400 square feet per gallon so as to thoroughly and uniformly cover the concrete surface. Areas of concrete which are porous, and appear dry, shall be given a second coat of primer.

On vertical curb and header surfaces, the primer shall be applied and finished off, in a neat line, to a height that will be one inch ± higher than the height of the completed asphalt overlay. The outside face of metal scuppers shall not be primed. The inside surfaces of subdrainage outlets (weep tubes) shall be primed to a depth of at least 3 inches.

The primer shall be allowed to dry to a "tack-free" condition prior to application of the preformed membrane. This time, which is dependent on temperature and humidity, is normally one hour. Excess primer, occurring as "puddles" or wet areas, shall be removed by brushes, or as directed by the Engineer.

Primed areas which have not been covered with preformed membrane within 36 hours after the application of primer, shall be re-primed.

Primed surfaces which, as determined by the Engineer, have become contaminated by dust and dirt shall be re-primed.

The appearance of bubbles in the primer is normal, due to out-gassing of air and moisture in the concrete. After the primer has dried to a "tack-free" condition, these bubbles shall be broken with squeegees or brooms. Unless otherwise directed by the Engineer, it shall not be necessary to repair the areas where bubbles have been broken.

D. Preformed Membrane Installation.

Heavy-duty bituthene preformed membrane shall be applied to primed surfaces no later than 36 hours after primer application.

Rolls of membrane may be applied by hand or mechanical means. The membrane shall be placed on the structural slab sticky side down, by removing the release paper as the work progresses. Preformed membrane flashing strips shall be placed and turned up the faces of curbs and headers and scuppers to a height equal to the thickness of bituminous overlay. Rolls of membrane shall be placed in such a manner as to minimize wrinkles and bubbles, but shall not be stretched or otherwise placed in tension. Squeegees shall be used, at the time of application, to smooth the membrane at its point of contact with the structural slab.

To insure adhesion to the structural slab, the preformed membrane shall be rolled with a pneumatic tired roller. Rolling shall be done at the end of each day's work, as applicable.

The preformed bridge membrane shall be laid longitudinally on the structural slab in the direction opposite to that of bituminous paving so that end laps are formed in the direction of bituminous paving. It shall be placed from a low to a high area and in such a manner as to produce a "shingling" effect to drain any water that accumulates toward the curb and scuppers. Adjacent rolls of membrane shall overlap a minimum of 2-1/2 inches and 8 inches on end laps. Laps which have not been thoroughly sealed by rolling operations shall be sealed with Bituthene Mastic Sealer.

The application of preformed membrane shall commence at the curb section(s). First, "flashing" strips, cut from rolls of preformed membrane, shall be applied on the curb face to a height equal to the depth of bituminous overlay. The strips shall extend a minimum of 6 inches on the structural slab and shall be thoroughly pressed into contact with the concrete surfaces.

On granite or other rough curb faces, beads of Bituthene Mastic shall be applied to the vertical face, to insure bonding of the flashing strips. The first full roll of preformed membrane sheet

shall then be aligned parallel to and applied on the structural slab as close as possible to the curb face. Wrinkles, "fishmouths" or other membrane defects occurring at the curb face shall be sealed against water intrusion by using Bituthene Mastic and/or patch strips. Finally, a bead of mastic sealer shall be applied along the entire length of curb face, at the termination edge of the membrane flashing strip.

Flashing strips of membrane shall be applied to the outside faces of headers and scuppers. The strips shall be placed on the vertical faces to the height of the asphalt overlay, and shall extend a minimum of 6 inches on the structural slab. The strips shall be pressed into contact with the vertical surface. If necessary, mastic sealer shall be used to insure adhesion. The preformed membrane sheet shall then be applied on the structural slab as close as possible to the vertical face. Any wrinkles, "fish-mouths" or other defects shall be corrected using mastic sealer and/or patches. A beam of mastic sealer shall be applied to the vertical face at the termination edge of the membrane flashing strip.

The termination edge of the membrane at deck ends and expansion joints constructed without headers shall be sealed with mastic sealer.

At subsurface drains, pieces of membrane flashing strip shall be applied to that area of structural slab within 6 inches of the drain opening. The full preformed membrane shall then be placed over the strips to provide double cover. At the subsurface drain, the pre-formed membrane shall be pierced and the edges turned down and adhered to the inside drain surface. If necessary, mastic sealer shall be used to insure adhesion of the membrane and to prevent the seepage of water under the membrane. Five-inch square pieces of wire mesh shall be pressed into a coat of mastic sealer, applied over the membrane at each subdrainage opening. Payment for wire mesh shall be included in this item.

When only a portion of the work area is completed in one day, the exposed edge of the membrane shall be sealed with mastic sealer.

The completed membrane shall be free of large wrinkles, "fish-mouths," air bubbles and other placement defects. These shall be corrected as directed by and to the satisfaction of the Engineer. When patches are used, the pieces of membrane patch shall be pressed into contact with the membrane sheet. The patch shall extend at least 4 inches in every direction beyond the edge of the defect. The edges of the patch shall be sealed with mastic sealer. Bubbles of one-inch diameter and greater shall be vented by piercing with an ice pick, or other suitable instrument, and expelling the air. Vented bubbles are self-sealing and need not be repaired.

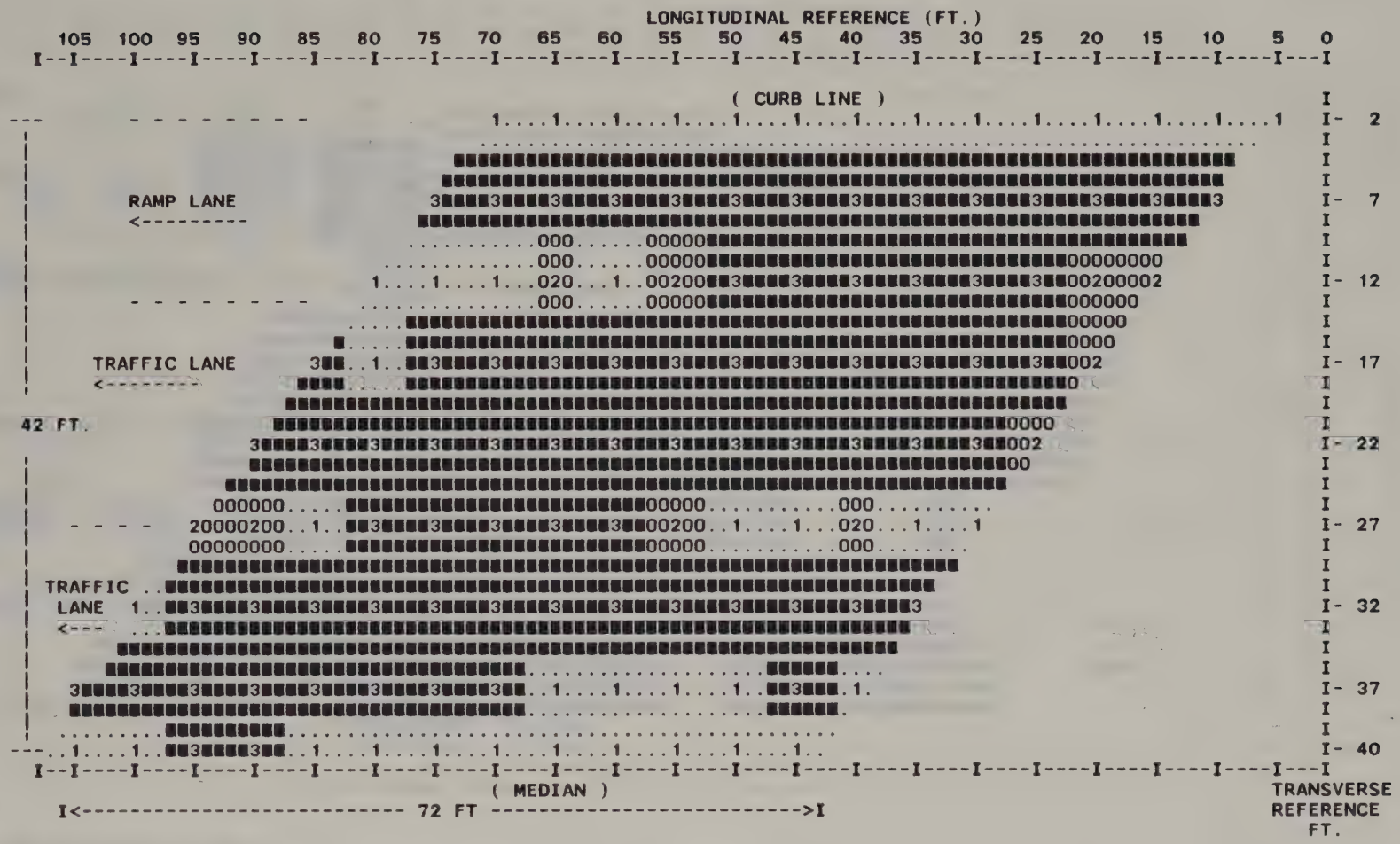
METHOD OF MEASUREMENT:

The work shall be measured as the number of square feet of actual horizontal surface area of the structural slab covered with the complete membrane waterproofing system. No separate measurement of the vertical faces of curbs, headers and scuppers, or for the inside surfaces of subdrainage outlets, shall be made. No measurement shall be made for laps.

BASIS OF PAYMENT:

The unit price bid per square foot for this item, shall include the cost of furnishing all labor, materials (including wire mesh) and equipment necessary to complete the work.

Figure 2. 1984 Electrical Resistance- Heavy Duty Bituthene- Span 1



NORTH

ELECTRICAL RESISTANCE DC
TEST DATE 10/02/84.
HEAVY DUTY BITUTHENE
IN SERVICE -- 8 YRS

BRIDGE DECK TEST SITE
CORNING RR BRIDGE
SPAN 1
BIN 1011200

CORNING RR BRIDGE SPAN 1

RESISTANCE DC DATA FOR 1984

DATA VALUE EXTREMES ARE 6.00 9999.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	100.00	501.00
MAXIMUM	100.00	501.00	10000.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1.00 4.01 94.99

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
FREQ.	41	10	74

Figure 3. 1984 Electrical Resistance - Heavy Duty Bituthene - Span 2

NORTH

TEST DATE 10/02/84.
ELECTRICAL RESISTANCE DC
HEAVY DUTY BITUTHENE
IN SERVICE -- 8 YRS

BRIDGE DECK TEST SITE
CORNING RR BRIDGE
SPAN 2
BIN 1011200

CORNING RR BRIDGE SPAN 2

ELECTRICAL RESISTANCE DC FOR 1984

DATA VALUE EXTREMES ARE 5.00 9999.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	100.00	501.00
MAXIMUM	100.00	501.00	10000.00

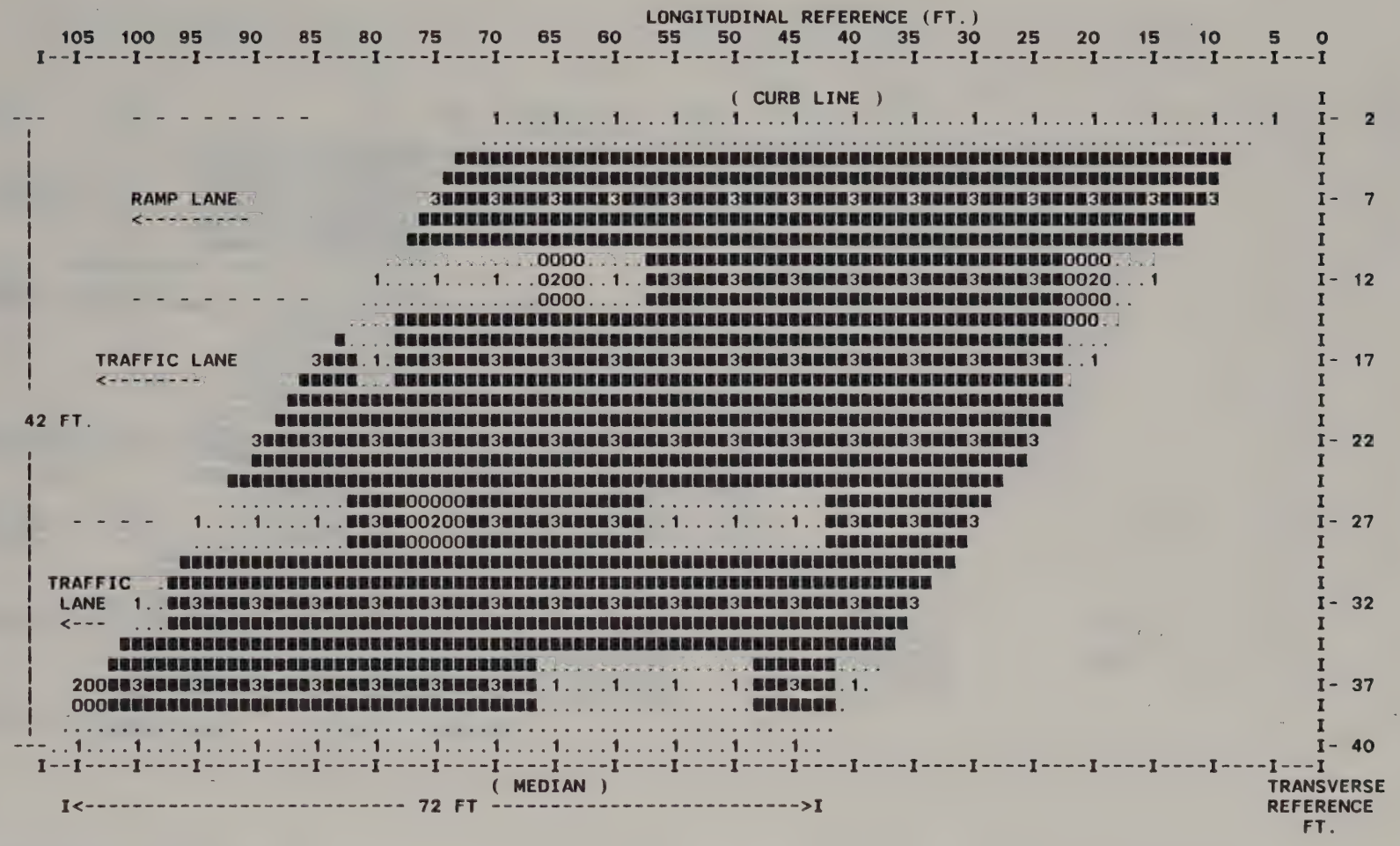
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1.00 4.01 94.99

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
FREQ.	51	12	136

Figure 4. 1989 Electrical Resistance - Heavy Duty Bituthene - Span 1



NORTH

ELECTRICAL RESISTANCE DC
TEST DATE 10/23/89.
HEAVY DUTY BITUTHENE
IN SERVICE -- 13 YRS

BRIDGE DECK TEST SITE
CORNING RR BRIDGE
SPAN 1
BIN 1011200

CORNING RR BRIDGE SPAN 1

RESISTANCE DC DATA FOR 1989

DATA VALUE EXTREMES ARE 1.00 9999.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	100.00	501.00
MAXIMUM	100.00	501.00	10000.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1.00	4.01	94.99

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	==========	==========	==========
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
	==========	==========	==========
FREQ.	46	4	75

Figure 5. 1989 Electrical Resistance - Heavy Duty Bituthene - Span 2

NORTH

TEST DATE 10/23/89.
ELECTRICAL RESISTANCE DC
HEAVY DUTY BITUTHENE
IN SERVICE -- 13 YRS

BRIDGE DECK TEST SITE
CORNING RR BRIDGE
SPAN 2
BIN 1011200

CORNING RR BRIDGE SPAN 2

ELECTRICAL RESISTANCE DC FOR 1989

DATA VALUE EXTREMES ARE 1.00 9999.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	100.00	501.00
MAXIMUM	100.00	501.00	10000.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1.00 4.01 94.99

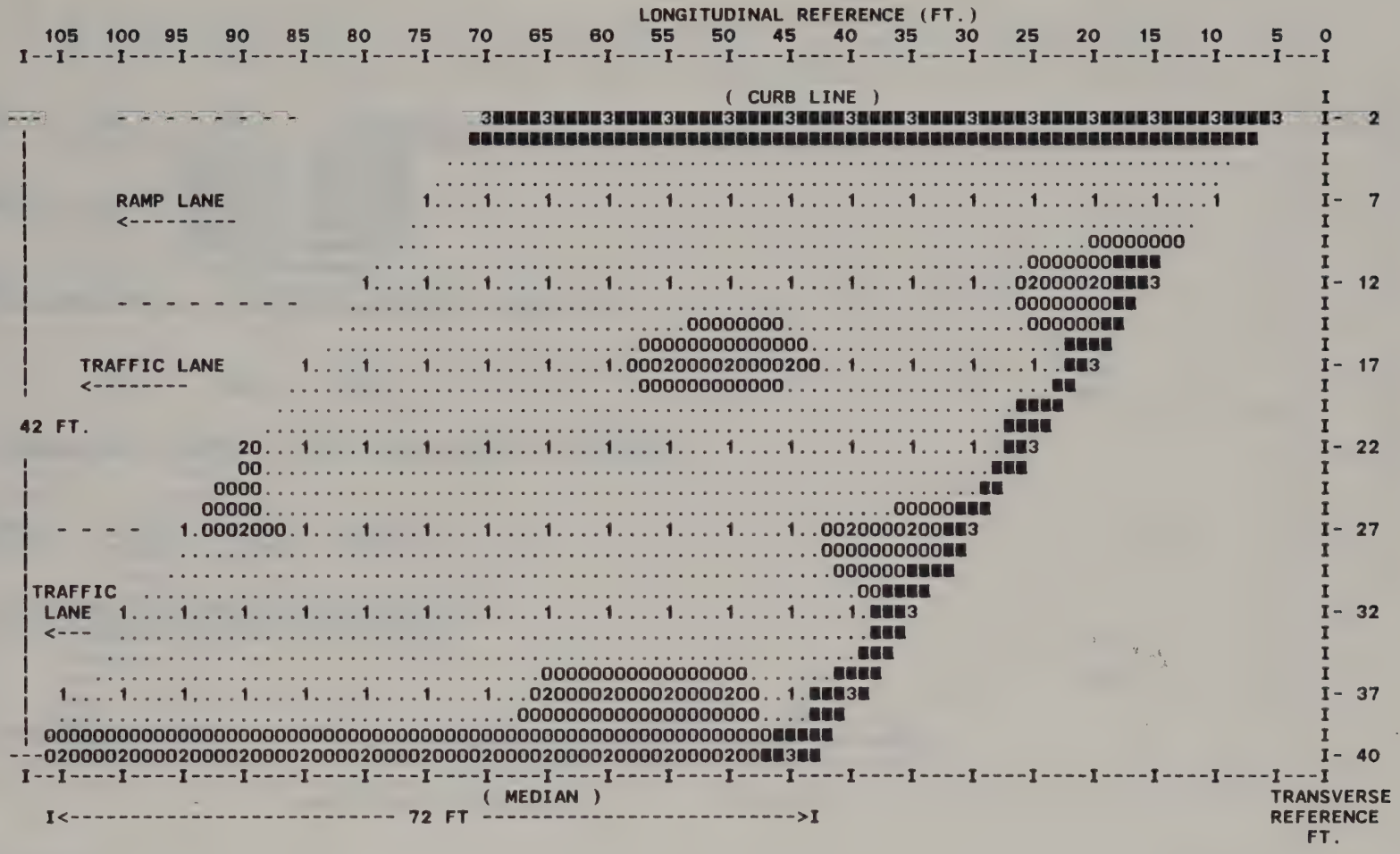
FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
FREQ.	63	13	118

0.1 MINUTES ELAPSED TIME FOR HISTOGRAM
0.0 MINUTES TOTAL PROCESSOR TIME
0.2 MINUTES TOTAL IO TIME

TIME OF DAY = 15/39

Figure 6. 1984 Corrosion Potential - Heavy Duty Bituthene - Span 1



NORTH

TEST DATE 10/02/84.
CORROSION POTENTIAL
HEAVY DUTY BITUTHENE
IN SERVICE -- 8 YRS

BRIDGE DECK TEST SITE
CORNING RR BRIDGE
SPAN 1
BIN 1011200

CORNING RR BRIDGE SPAN 1

POTENTIAL DATA FOR 1984

DATA VALUE EXTREMES ARE 0.00 0.49

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	0.20	0.36
MAXIMUM	0.20	0.36	0.60

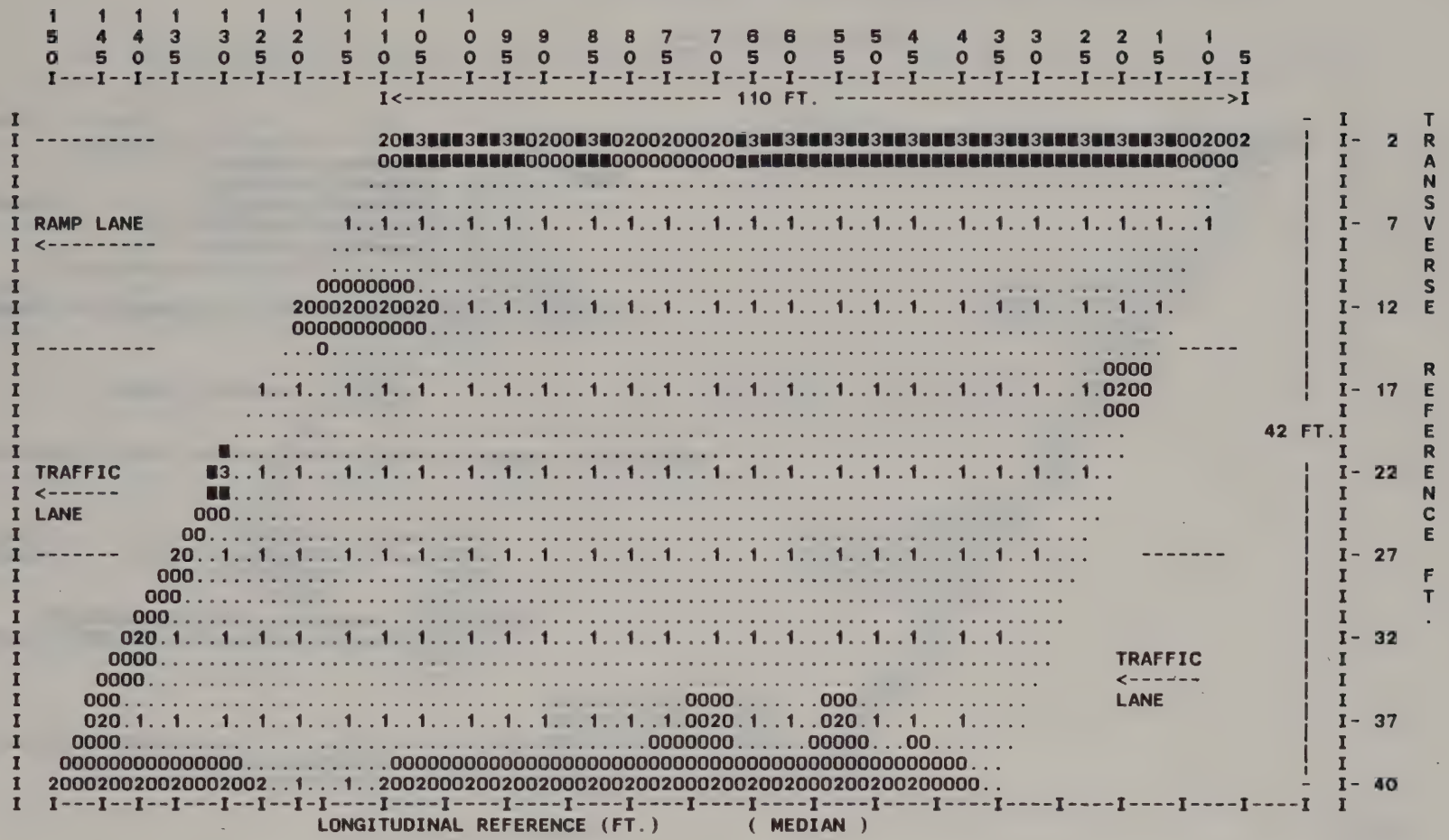
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

33.33 26.67 40.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	.....	000000000	■■■■■■■■■■
	.....	000000000	■■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■■
	.....	000000000	■■■■■■■■■■
FREQ.	79	25	21

Figure 7. 1984 Corrosion Potential - Heavy Duty Bituthene - Span 2



NORTH

TEST DATE 10/02/84.
CORROSION POTENTIAL
HEAVY DUTY BITUTHENE
IN SERVICE -- 8 YRS

BRIDGE DECK TEST SITE
CORNING RR BRIDGE
SPAN 2
BIN 1011200

CORNING RR BRIDGE SPAN 2

POTENTIAL DATA FOR 1984

DATA VALUE EXTREMES ARE 0.01 0.49

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	0.20	0.36
MAXIMUM	0.20	0.36	0.60

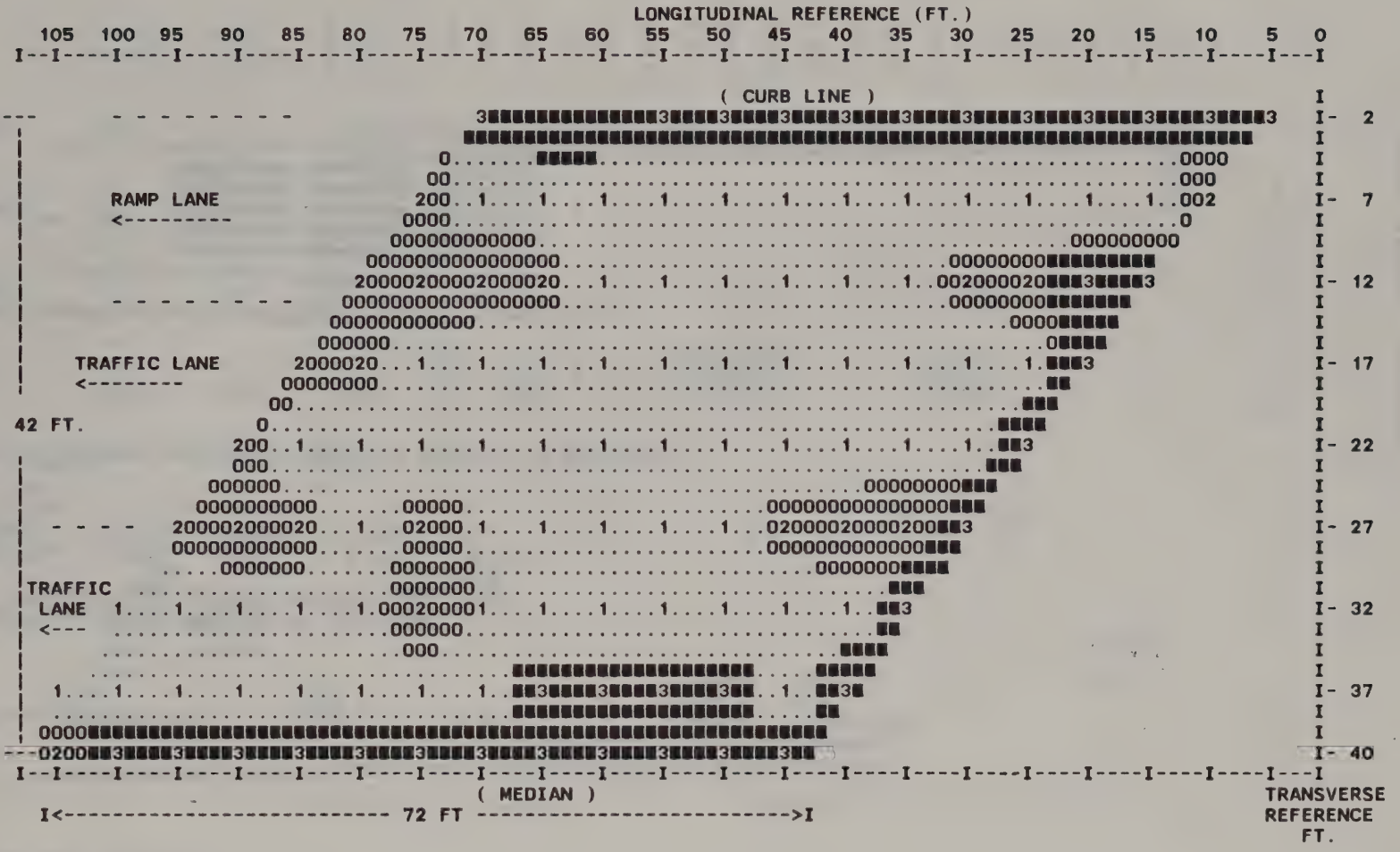
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

33.33 26.67 40.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
FREQ.	145	37	16

Figure 8. 1989 Corrosion Potential - Heavy Duty Bituthene - Span 1



NORTH

TEST DATE 10/23/89.
CORROSION POTENTIAL
HEAVY DUTY BITUTHENE
IN SERVICE -- 13 YRS

BRIDGE DECK TEST SITE
CORNING RR BRIDGE
SPAN 1
BIN 1011200

CORNING RR BRIDGE SPAN 1

POTENTIAL DATA FOR 1989

DATA VALUE EXTREMES ARE 0.01 0.63

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

				ABOVE
MINIMUM	0.00	0.20	0.36	0.60
MAXIMUM	0.20	0.36	0.60	

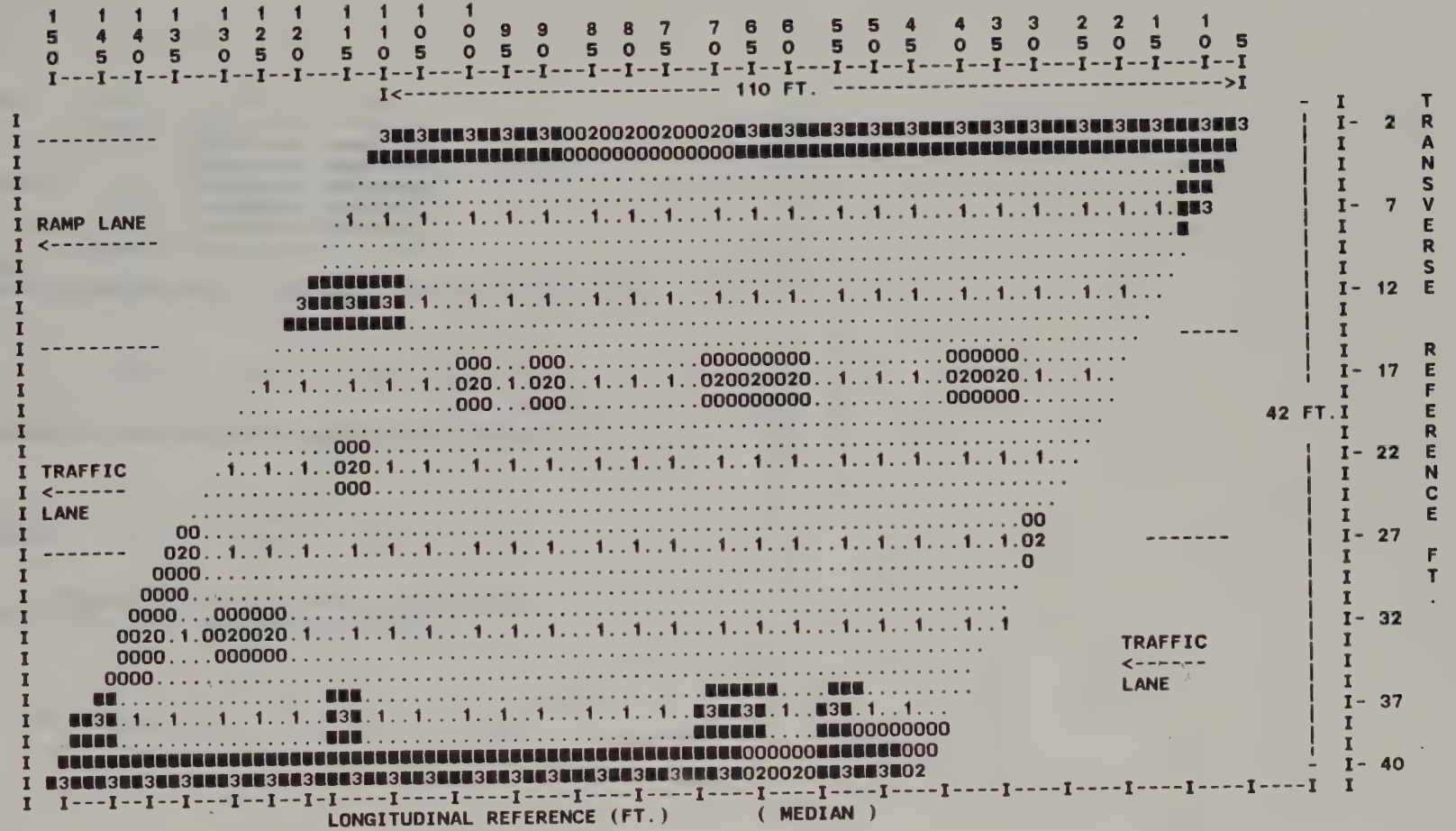
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

33.33 26.67 40.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	H
	.....	000000000	■■■■■■■■■	HHHHHHHHH
	.....	000000000	■■■■■■■■■	HHHHHHHHH
SYMBOLS	....1....	000020000	■■■■3■■■■	HHHHHHHHH
	.....	000000000	■■■■■■■■■	HHHHHHHHH
	.....	000000000	■■■■■■■■■	HHHHHHHHH
FREQ.	68	20	35	2

Figure 9. 1989 Corrosion Potential - Heavy Duty Bituthene - Span 2



NORTH

TEST DATE 10/23/89.
CORROSION POTENTIAL
HEAVY DUTY BITUTHENE
IN SERVICE -- 13 YRS

BRIDGE DECK TEST SITE
CORNING RR BRIDGE
SPAN 2
BIN 1011200

CORNING RR BRIDGE SPAN 2

POTENTIAL DATA FOR 1989

DATA VALUE EXTREMES ARE 0.00 0.47

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	0.20	0.36
MAXIMUM	0.20	0.36	0.60

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

33.33 26.67 40.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
FREQ.	128	20	46

APPENDIX B

Protecto-Wrap M-400A Membrane Waterproofing

ITEM BRIDGE PREFORMED MEMBRANE WATERPROOFING SYSTEM (PROTECTO WRAP M-400A

SCOPE:

This work shall consist of furnishing and applying a preformed membrane waterproofing system. It shall include, but not be limited to, the preparation of concrete surfaces; the application of cold applied primer, and preformed membrane as specified in Contract Documents.

MATERIALS:

The preformed membrane waterproofing system shall be as manufactured by Protecto Wrap Company, Denver, Colorado, and shall consist of the following materials:

Bridge Preformed Membrane - Protecto Wrap M-400A

Primer - Protecto Wrap No. 80 (or 8AP) Primer

Mastic Sealer - Protecto Wrap 160H Mastic

Wire Mesh for use over subdrainage openings, shall be a first class, 1/4-inch mesh by 23 gauge, hot-dipped galvanized cloth.

CONSTRUCTION DETAILS:

A. Preparation of Structural Slab Surfaces.

All structural slab surfaces that are to be waterproofed, including vertical surfaces, shall be prepared and cleaned as follows: Unless otherwise directed by the Engineer, work shall not begin on new structural slabs until a minimum of 28 days after concrete placement.

1. All loose material, including dirt, stones, gravel and concrete laitance shall be removed by vacuuming or blowing with compressed air.

2. Any excess laitance (surface film of concrete), road oil, other bituminous based contaminates, and other foreign materials, including concrete curing compounds, which are detrimental to membrane adhesion shall be removed by sandblasting or wire brushing and washing with water or a combination of these methods. To determine if adhesion problems exist, small test patches of primer and membrane shall be applied to the area(s) in question. These test patches shall then be checked by the Engineer to determine the compatibility and adhesion of the membrane to the concrete surface.

3. All surface projections, including exposed aggregate or any other conditions which have presented so rough a concrete surface, as determined by the Engineer to be detrimental to the membrane, shall be ground smooth, or grouted smooth with cement mortar or epoxy. If grouting materials are used, they shall be "set up" and surface dry, prior to application of primer. Cement mortar mixes for use in grouting shall be approved by the Engineer prior to use. Epoxy mortar materials shall consist of epoxy material meeting the requirements of Material Specifications 721-01, 721-02 or 721-03, and fine aggregate as approved by the Engineer.

4. Immediately prior to primer application, surfaces to be primed shall be re-cleaned of dust and other loose foreign material by vacuuming or blowing with compressed air.

B. Atmospheric Conditions.

Work shall not be done during wet weather conditions nor, when determined by the Engineer atmospheric conditions are such as to produce unsatisfactory results. No work shall be done when the structural slab surface temperature is below 50°F. and ambient temperatures are below 50°F. The concrete structural slab shall be surface dry at the time of primer application.

C. Primer Application.

After cleaning, all concrete surfaces to be waterproofed shall be primed with Protecto Wrap No. 80 Primer. The primer shall be thoroughly mixed, prior to use. Mixing shall be done with mechanical mixers or hand mixed, using clean paddles or other suitable instruments. All settled material shall be thoroughly dispersed.

The primer shall be applied, without dilution, by the use of brushes or rollers, or squeegees or a combination of these methods. Spray application of primer will not be allowed. The primer shall be applied at such a rate as to thoroughly and uniformly cover the concrete surface. Normal application rate of primer is 110 sq-ft/gal, but depending on the porosity and texture of the concrete surface, the application rate may vary from 80 to 150 sq-ft/gal.

On vertical curb and header surfaces, the primer shall be applied and finished off, in a neat line, to a height that will be one inch ± higher than the top of the upturned edge of the preformed membrane overlay. The entire outside face of scuppers shall be primed. The inside surfaces of subdrainage outlets (weep tubes) shall be primed to a depth of at least 3 inches.

The primer shall be allowed to dry to a "tack-free" condition, prior to application of the preformed membrane. This time, which is dependent upon temperature and humidity, is normally 1/2 to 1-1/2 hours. Excess primer, occurring as "puddles" or wet areas, shall be removed by brushes, or as directed by the Engineer.

Primed surfaces which have not been covered with preformed membrane within 24 hours after the application of primer shall be re-primed.

Primed surfaces which, as determined by the Engineer, have become contaminated by dust and dirt shall be re-primed.

The appearance of bubbles in the primer is normal, due to out-gassing of air and moisture in the concrete. After the primer has dried to a "tack-free" condition, these bubbles shall be broken with squeegees or brooms. Unless otherwise directed by the Engineer, it shall not be necessary to repair the areas where bubbles have been broken.

D. Preformed Membrane Installation.

Protecto Wrap M400A Membrane shall be applied to primed surfaces no later than 24 hours after primer application.

Rolls of preformed membrane may be applied by hand or mechanical means. The membrane shall be placed on the structural slab, sticky side down, and shall be turned up the faces of curbs and headers and scuppers to a height equal to the thickness of bituminous overlay. To minimize wrinkles and bubbles, rolls of membrane shall be "stretched" into place and squeegees shall be used, at the time of application, to smooth the membrane at its point of contact with the structural slab.

To minimize damage from foot traffic and rolling operations, the polyethylene release film, except for the perforated edge strip, shall remain in place until just prior to paving the bituminous overlay. The perforated edge strip of polyethylene film shall be removed at the time of placement and alignment of an adjacent roll of membrane. Spliced rolls of membrane have release film on the bottom (sticky side). Care shall be taken to insure removal of the polyethylene film from the spliced areas at the time of membrane application.

To insure adhesion to the structural slab, the preformed membrane shall be rolled with pneumatic tired roller. Rolling shall be done after placement of the membrane or at the end of each day's work, as applicable.

The preformed bridge membrane shall be laid longitudinally on the structural slab, in the direction opposite that of bituminous paving, so that end laps are formed in the direction of bituminous paving. It shall be placed from a low to a high area and in such a manner as to produce a "shingling" effect to drain any water that accumulates toward the curb and scuppers. Adjacent rolls of preformed membrane shall overlap a minimum of 2 inches and a minimum of 8 inches on end laps. If dirt or dust has contaminated exposed edges, primer shall be applied to the contaminated areas to seal the overlaps.

The application of preformed membrane shall commence at the curb section(s). The vertical face of the curb shall be coated with Protecto Wrap 160 H sealer. The mastic sealer shall be applied as a smooth

uniform coat. The preformed membrane shall be aligned parallel to and be brought up the face of the curb to a height equal to the depth of bituminous overlay. The membrane shall be thoroughly pressed into the mastic sealer. Wrinkles or "fishmouths" or other membrane defects occurring at the curb face shall be sealed against water intrusion by the use of additional mastic sealer and/or patch strips. Finally, a bead of mastic sealer shall be applied along the entire length of curb face, at the termination edge of the membrane.

The outside face of headers and scupper frames shall be coated with mastic sealer. The membrane shall be turned up and pressed into the sealer to the height of the asphalt overlay. Any wrinkles and "fishmouths" shall be sealed with additional mastic sealer and/or patches. A bead of mastic sealer shall be applied at the termination edge of the membrane.

The termination edge of the membrane at deck ends and expansion joints constructed without headers shall be sealed with mastic sealer.

At subsurface drains, mastic sealer shall be applied to the area of structural deck slab within 6 inches of the drain and to the inside surfaces of the drain, to a depth of 3 inches. The membrane shall be pierced at the drain and the edges turned down and pressed into the mastic sealer. Five-inch square pieces of wire mesh shall be pressed into a coat of mastic sealer, applied over the membrane at each subdrainage opening. Payment for wire mesh shall be included in this item.

When only a portion of the work area is completed in one day, the exposed edge of the membrane shall be sealed with mastic sealer.

The completed membrane shall be free of large wrinkles, "fishmouths," air bubbles and other placement defects. These shall be corrected as directed by and to the satisfaction of the Engineer. When patches are used, the area shall be coated with mastic sealer and pieces of membrane pressed into the sealer over the defective area. The patches shall extend at least 6 inches in every direction beyond the edge of the defect. Bubbles of one-inch diameter and greater shall be vented by piercing with an ice pick, or other suitable instrument, and expelling the air. Vented bubbles are self-sealing and need not be repaired.

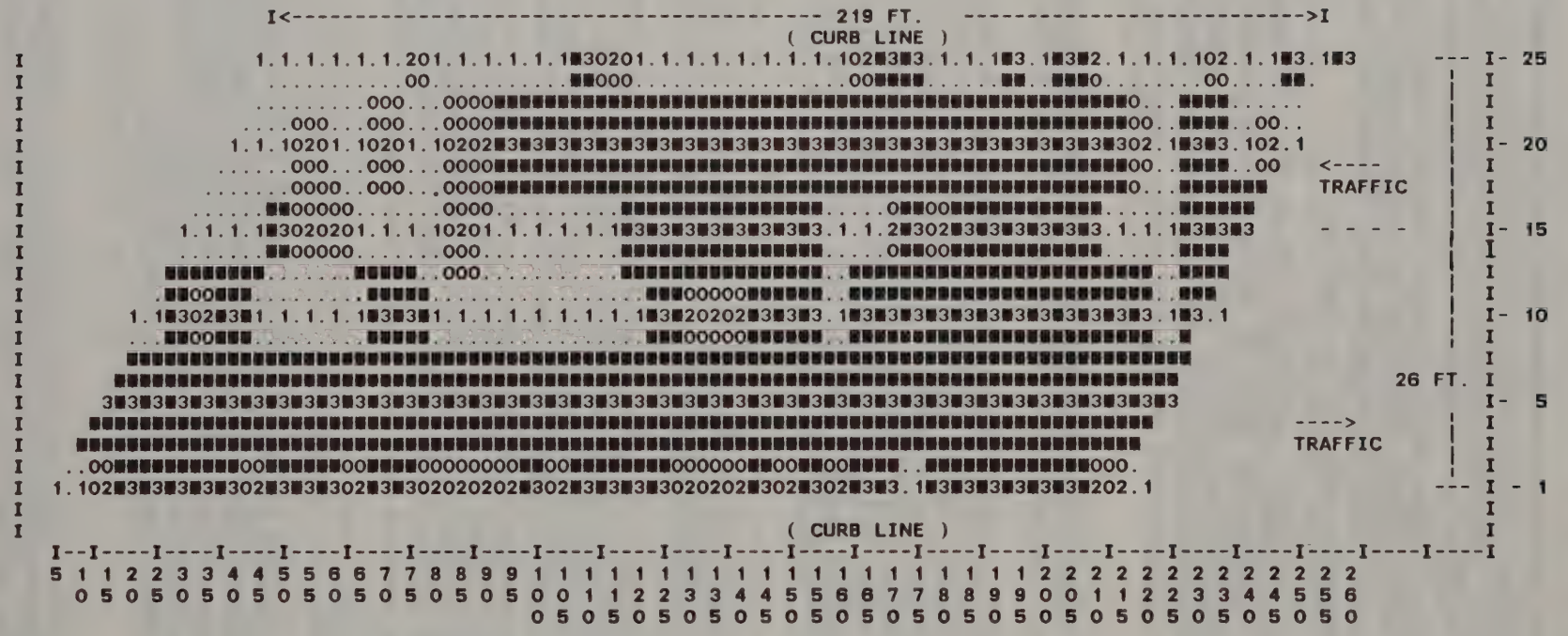
METHOD OF MEASUREMENT:

The work shall be measured as the number of square feet of actual horizontal surface area of the structural slab covered with the complete membrane waterproofing system. No separate measurement of the vertical faces of curbs, headers and scuppers or for the inside surfaces of subdrainage outlets shall be made. No measurement shall be made for laps.

BASIS OF PAYMENT:

The unit price bid per square foot for this item shall include the cost of furnishing all labor, materials (including wire mesh) and equipment necessary to complete the work.

Figure 10. 1984 Electrical Resistance - Protecto Wrap M-400A



CAYUTA CREEK BRIDGE

RESISTANCE DC DATA FOR 1984

DATA VALUE EXTREMES ARE 0.00 9999.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	100.00	501.00
MAXIMUM	100.00	501.00	10000.00

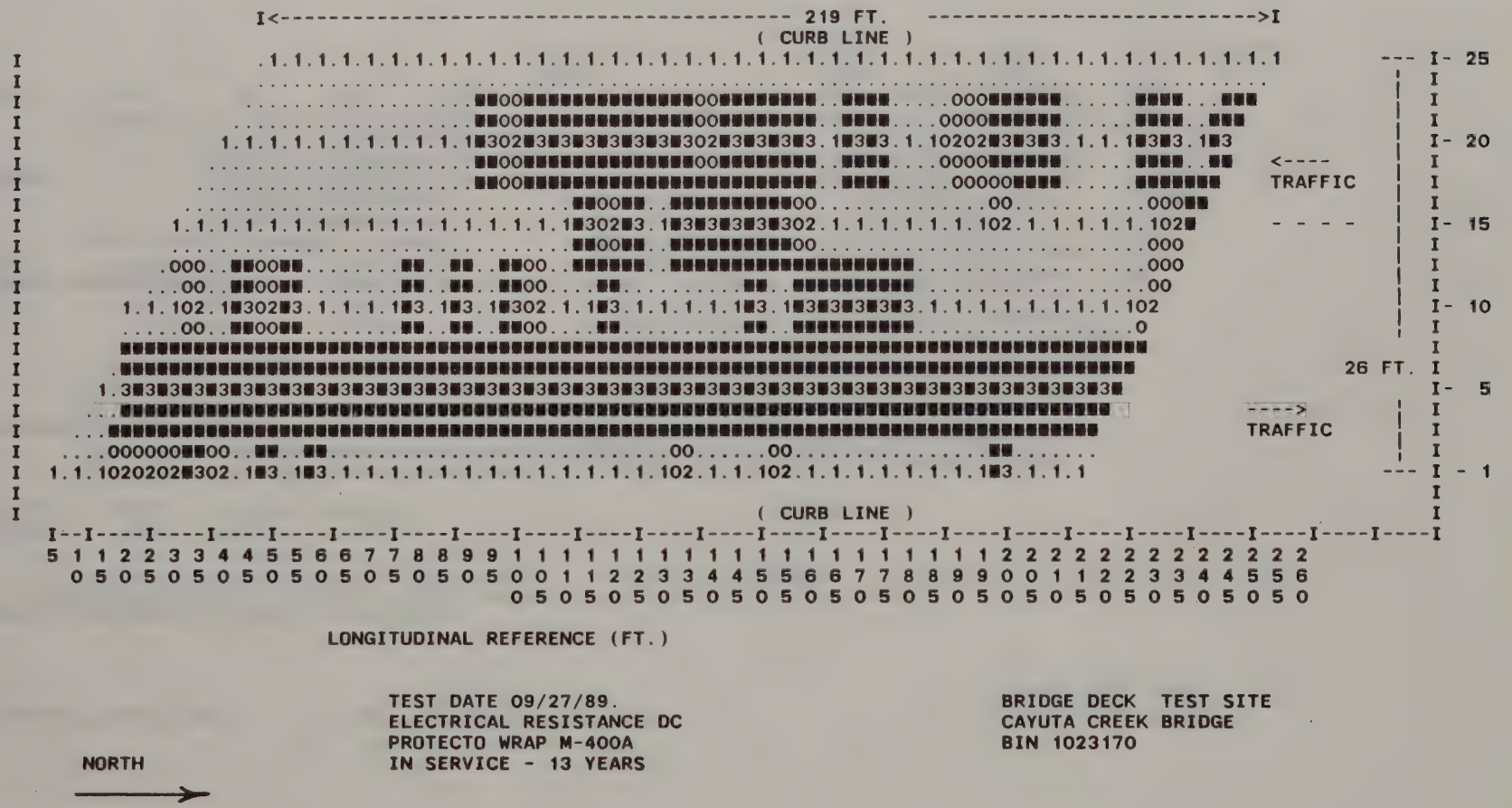
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1.00	4.01	94.99

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
		000000000	■■■■■■■■■
		000000000	■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
		000000000	■■■■■■■■■
		000000000	■■■■■■■■■
FREQ.	84	35	142

Figure 11. 1989 Electrical Resistance - Protecto Wrap M-400A



CAYUTA CREEK BRIDGE

RESISTANCE DC DATA FOR 1989

DATA VALUE EXTREMES ARE 4.00 9999.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	100.00	501.00
MAXIMUM	100.00	501.00	10000.00

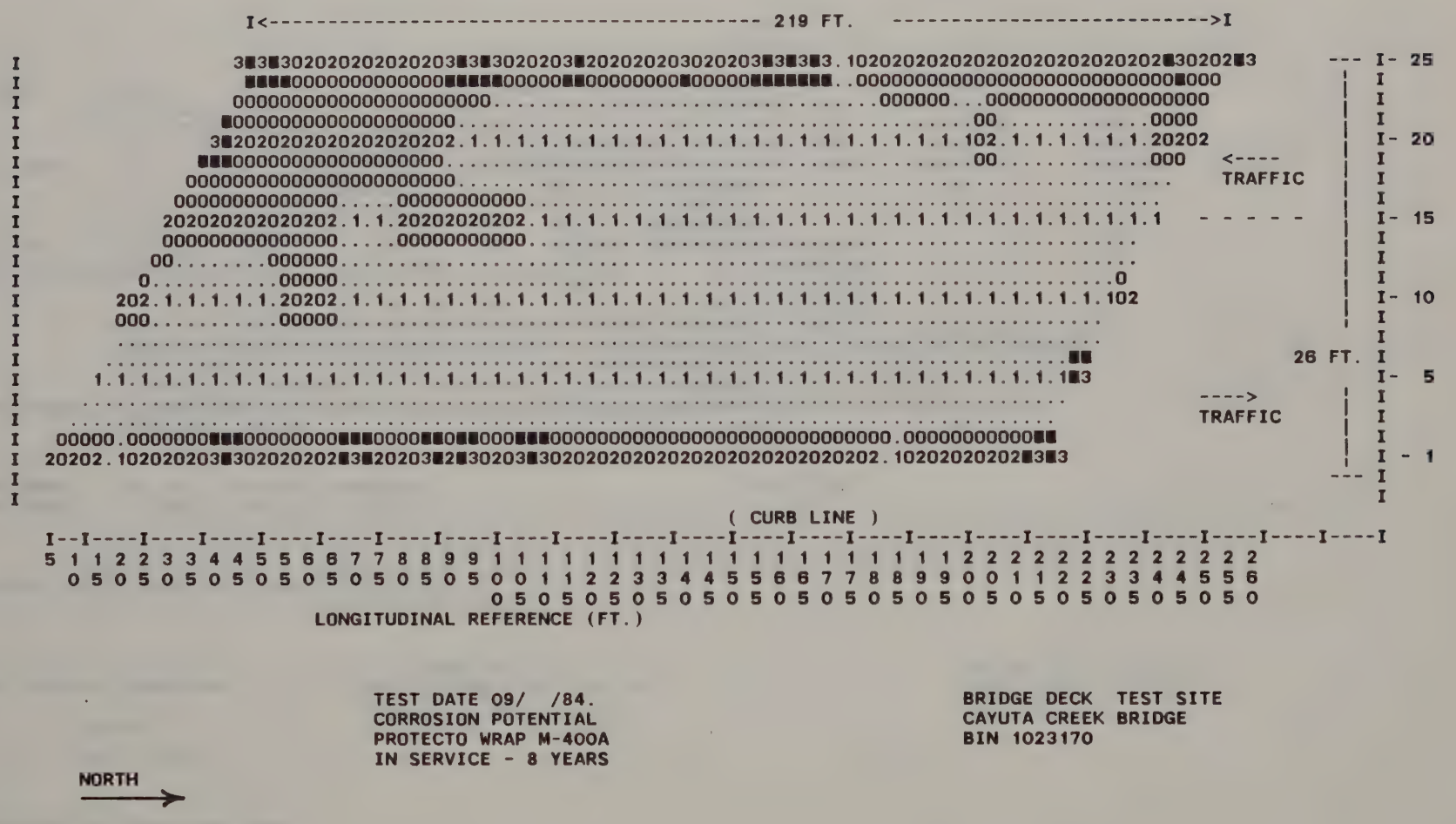
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1.00	4.01	94.99

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
FREQ.	152	18	84

Figure 12. 1984 Corrosion Potential - Protecto Wrap M-400A



CAYUTA CREEK BRIDGE

POTENTIAL DATA FOR 1984

DATA VALUE EXTREMES ARE 0.00 0.47

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	0.20	0.36
MAXIMUM	0.20	0.36	0.60

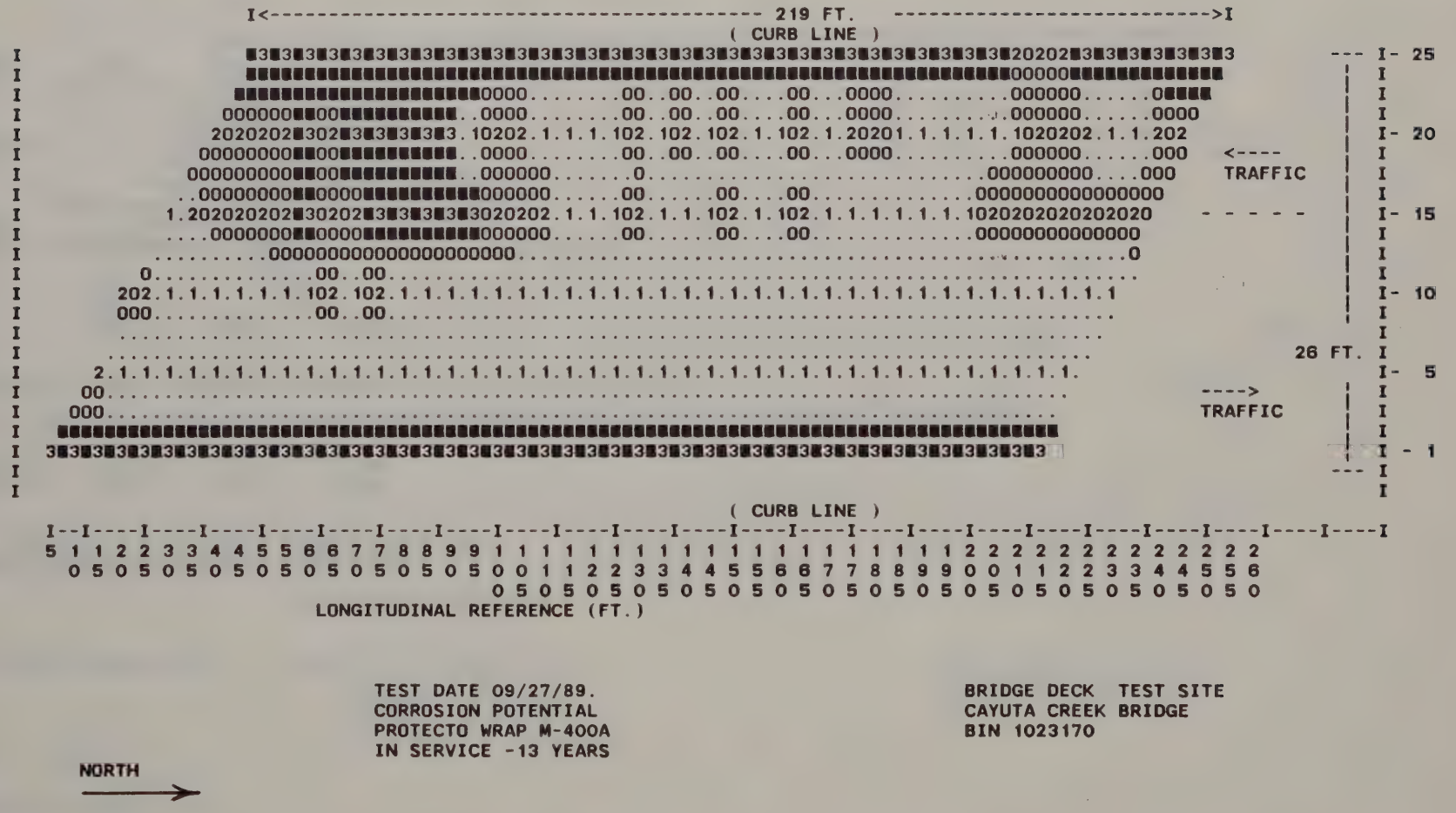
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

33.33 26.67 40.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
FREQ.	140	98	25

Figure 13. 1989 Corrosion Potential - Protecto Wrap M-400A



CAYUTA CREEK BRIDGE

POTENTIAL DATA FOR 1989

DATA VALUE EXTREMES ARE 0.01 0.55

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	0.20	0.36
MAXIMUM	0.20	0.36	0.60

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

33.33	26.67	40.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
FREQ.	114	46	94

APPENDIX C

Royston Bridge Membrane No. 10

ITEM BRIDGE PREFORMED MEMBRANE WATERPROOFING SYSTEM
(ROYSTON BRIDGE MEMBRANE No. 10)

SCOPE:

This work shall consist of furnishing and applying a preformed membrane waterproofing system. It shall include, but not be limited to, the preparation of concrete surfaces; the application of cold applied primer, and preformed membrane as specified in the Contract Documents.

MATERIALS:

The preformed membrane waterproofing system shall be as manufactured by Royston Laboratories, Inc., Pittsburgh, Pennsylvania, and shall consist of the following materials:

Bridge Preformed Membrane - Royston Bridge Membrane No. 10

Primer - Royston Bridge Membrane Primer 713

Mastic Sealer - Royston Roskote A-51 Black Mastic

Wire Mesh for use over subdrainage openings shall be a first class, 1/4-inch mesh by 23 gauge, hot-dipped galvanized cloth.

CONSTRUCTION DETAILS:

A. Preparation of Structural Slab Surfaces.

All structural slab surfaces that are to be waterproofed, including vertical surfaces, shall be prepared and cleaned as follows: Unless otherwise directed by the Engineer, work shall not begin on new structural slabs until a minimum of 28 days after concrete placement.

1. All loose material, including dirt, stones, gravel and concrete laitance shall be removed by vacuuming or blowing with compressed air.

2. Any excess laitance (surface film of concrete), road oil, other bituminous based contaminants, and other foreign materials, including concrete curing compounds, which are detrimental to membrane adhesion shall be removed by sandblasting or wire brushing and washing with water or a combination of these methods. To determine if adhesion problems exist, small test patches of primer and membrane shall be applied to the area(s) in question. These test patches shall then be checked by the Engineer to determine the compatibility and adhesion of the membrane to the concrete surface.

3. All surface projections, including exposed aggregate or any other conditions which have presented so rough a concrete surface, as determined by the Engineer to be detrimental to the membrane,

shall be ground smooth, or grouted smooth with cement mortar or epoxy. If grouting materials are used, they shall be "set up" and surface dry, prior to application of primer. Cement mortar mixes for use in grouting shall be approved by the Engineer prior to use. Epoxy mortar materials shall consist of epoxy material meeting the requirements of Material Specifications 721-01, 721-02 or 721-03, and fine aggregate as approved by the Engineer.

4. Immediately prior to primer application, surfaces to be primed shall be re-cleaned of dust and other loose foreign material by vacuuming or blowing with compressed air.

B. Atmospheric Conditions.

Work shall not be done during wet weather conditions nor, when determined by the Engineer, atmospheric conditions are such as to produce unsatisfactory results. No work shall be done when the structural slab surface temperature is below 50°F and ambient temperatures are below 50°F. The concrete structural slab shall be surface dry at the time of primer application.

C. Primer Application.

After cleaning, all concrete surfaces to be waterproofed shall be primed with Royston Bridge Membrane Primer 713. The primer shall be thoroughly mixed prior to use.

Mixing shall be done by hand only, using clean paddles or other suitable instruments.

The primer shall be applied, without dilution, by the use of brushes or rollers or squeegees or a combination of these methods. Spray application of primer shall not be allowed. The primer shall be applied at an average rate of 90 square feet per gallon and in such a manner as to thoroughly and uniformly cover the concrete surface.

On vertical curb and header surfaces, the primer shall be applied and finished off, in a neat line, to a height that will be one inch ± higher than the upturned edge of the preformed membrane overlay. The entire outside face of scuppers shall be primed. The inside surfaces of subdrainage outlets (weep tubes) shall be primed to a depth of at least 3 inches.

The primer shall be thoroughly dry prior to application of the preformed membrane. Drying time, which is dependent upon temperature and humidity is normally one-half hour. Excess primer, occurring as "puddles" or wet areas, shall be removed by brushes, or as directed by the Engineer.

Primed surfaces which have not been covered with preformed membrane within 24 hours after the application of primer, shall be re-primed.

Primed surfaces which, as determined by the Engineer, have become contaminated by dust and dirt shall be re-primed.

The appearance of bubbles in the primer is normal, due to out-gassing of air and moisture in the concrete. After the primer has dried to a "tack-free" condition, these bubbles shall be broken with squeegees or brooms. Unless otherwise directed by the Engineer, it shall not be necessary to repair the areas where bubbles have been broken.

D. Preformed Membrane Installation.

Royston Bridge Membrane No. 10 shall be applied to primed surfaces no later than 24 hours after primer application.

Rolls of membrane may be applied by hand or mechanical means. The membrane shall be placed on the structural slab sticky side down, by removing the release paper as the work progresses. The preformed membrane shall be turned up the faces of curbs and headers and scuppers to a height equal to the thickness of bituminous overlay. The membrane shall be placed in such a manner as to minimize wrinkles and bubbles but shall not be stretched or otherwise placed in tension. Squeegees shall be used, at the time of application, to smooth the membrane at its point of contact with the structural slab.

To insure adhesion to the structural slab, the preformed membrane shall be hand-rolled with a 100-200 pound roller. Rolling shall be done after placement of the membrane on the structural slab surface or at the end of each day's work, as applicable.

The preformed bridge membrane shall be laid longitudinally on the structural slab in the direction opposite to that of bituminous paving so that end laps are formed in the direction of bituminous paving. It shall be placed from a low to a high area and in such a manner as to produce a "shingling" effect to drain any water that accumulates toward the curb and scuppers. Adjacent rolls of preformed membrane shall overlap a minimum of 2 inches and 8 inches on end laps. The narrow band of release paper which acts as an edge strip shall be removed from an applied roll to expose the sticky edge and to insure bonding with the underside of an adjacent roll and sealing of the lap. End laps shall be sealed by heating the membrane surface to be covered with a propane torch, melting the polyester film and fusing the applied surface to the underside of the covering roll.

The application of preformed membrane shall commence at the curb section(s). The preformed membrane shall be aligned parallel to and be brought up the face of the curb to a height equal to the depth of bituminous overlay. The up-turned portion of membrane shall be bonded to the curb face by the heat fusion method; by heating the sticky side of the membrane with a propane torch and pressing the heated membrane into contact with the curb face. Wrinkles or "fishmouths" or other

membrane defects occurring at the curb face shall be sealed against water intrusion by using mastic sealer (Royston Roskote A-41 Black Mastic) and/or patch strips. Finally, a bead of mastic sealer shall be applied along the entire length of curb face, at the termination edge of the membrane.

The membrane shall be turned up the outside face of headers and scupper frames to the height of the asphalt overlay. The membrane shall be adhered to these surfaces by the heat-fusion method. Any wrinkles and "fishmouths" shall be sealed, using mastic sealer and/or patches. A bead of mastic sealer shall be applied at the termination edge of the membrane.

The termination edge of the membrane at deck ends and expansion joints constructed without headers shall be sealed with mastic sealer.

At subsurface drains, the membrane shall be pierced and the edges turned down and adhered to the inside drain surface by the heat-fusion method. If necessary, mastic sealer shall be applied to insure adhesion of the membrane and to prevent the seepage of water under the membrane. Five-inch square pieces of wire mesh shall be pressed into a coat of mastic sealer, applied over the membrane at each subdrainage opening. Payment for wire mesh shall be included in this item.

When only a portion of the work area is completed in one day, the exposed edge of the membrane shall be sealed with mastic sealer.

The completed membrane shall be free of large wrinkles, "fishmouths," air bubbles and other placement defects. These shall be corrected as directed by and to the satisfaction of the Engineer. When patches are used, the pieces of membrane patch shall be affixed by the heat-fusion method and pressed into contact with the membrane sheet. The patch shall extend at least 4 inches in every direction beyond the edge of the defect. The edges of the patch shall be sealed with mastic sealer. Bubbles of one inch diameter and greater shall be vented by piercing with an ice pick, or other suitable instrument, and expelling the air. Vented bubbles are self-sealing and need not be repaired.

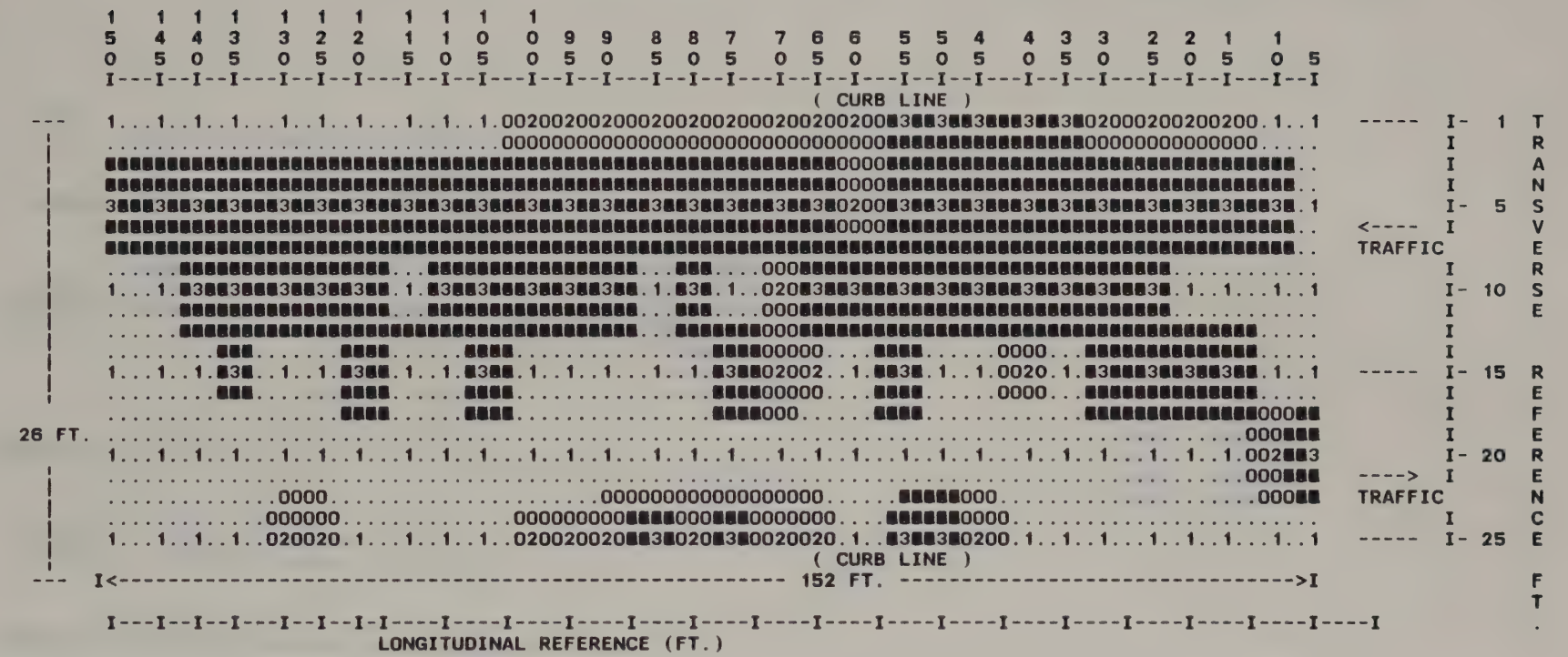
METHOD OF MEASUREMENT:

The work shall be measured as the number of square feet of actual horizontal surface area of the structural slab covered with the complete membrane waterproofing system. No separate measurement for the vertical faces of curbs, headers and scuppers or for the inside surfaces of subdrainage outlets shall be made. No measurement shall be made for laps.

BASIS OF PAYMENT:

The unit price bid per square foot for this item shall include the cost of furnishing all labor, materials (including wire mesh) and equipment necessary to complete the work.

Figure 14. 1984 Electrical Resistance - Royston Bridge Membrane No. 10



TEST DATE 09/ 7/84.
ELECTRICAL RESISTANCE DC
ROYSTON BRIDGE MEMBRANE NO. 10
IN SERVICE -- 8 YRS

BRIDGE DECK TEST SITE
WAVERLY RR BRIDGE
BIN 1023180

NORTH

WAVERLY RR BRIDGE

RESISTANCE DC DATA FOR 1984

DATA VALUE EXTREMES ARE 1.00 9999.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	100.00	501.00
MAXIMUM	100.00	501.00	10000.00

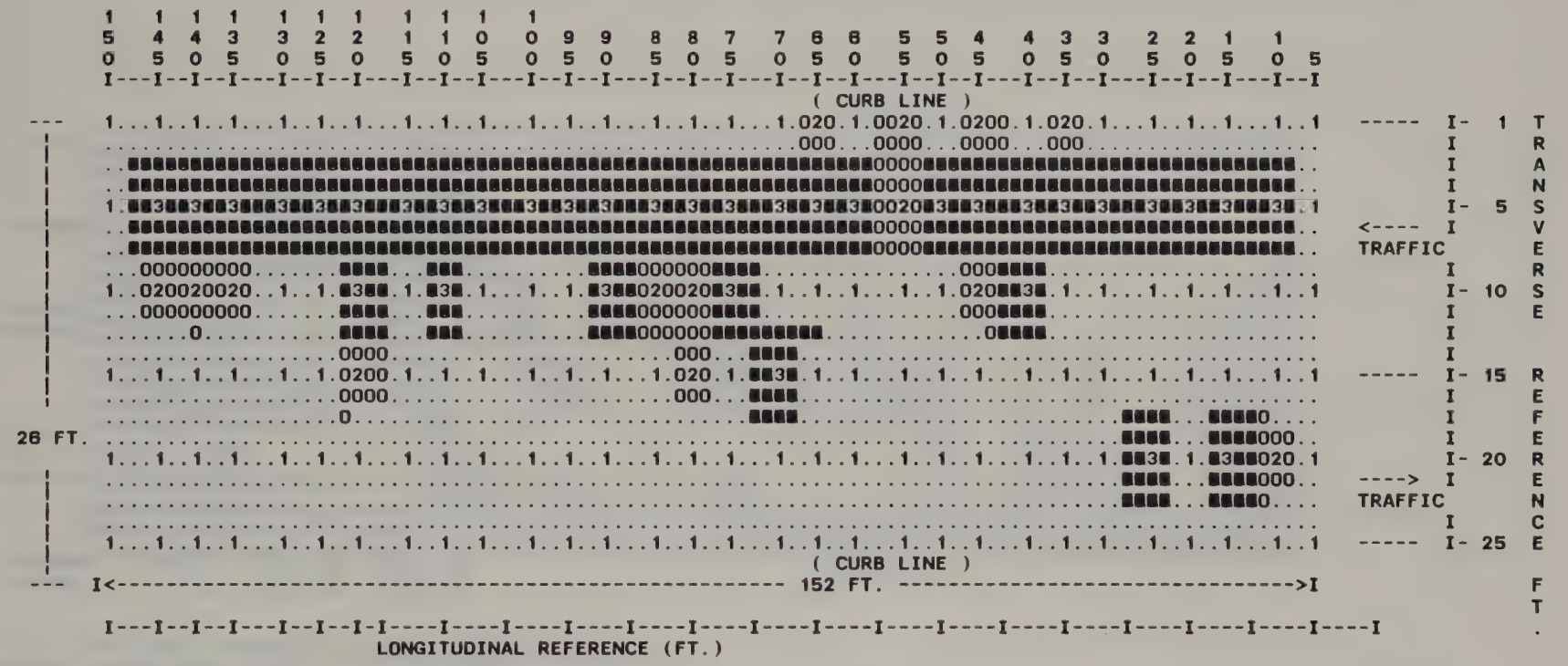
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1.00 4.01 94.99

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
FREQ.	85	28	67

Figure 15. 1989 Electrical Resistance - Royston Bridge Membrane No. 10



NORTH

TEST DATE 09/27/89.
ELECTRICAL RESISTANCE DC
ROYSTON BRIDGE MEMBRANE NO. 10
IN SERVICE -- 13 YRS

BRIDGE DECK TEST SITE
WAVERLY RR BRIDGE
BIN 1023180

WAVERLY RR BRIDGE

RESISTANCE DC DATA FOR 1989

DATA VALUE EXTREMES ARE 4.00 9999.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	100.00	501.00
MAXIMUM	100.00	501.00	10000.00

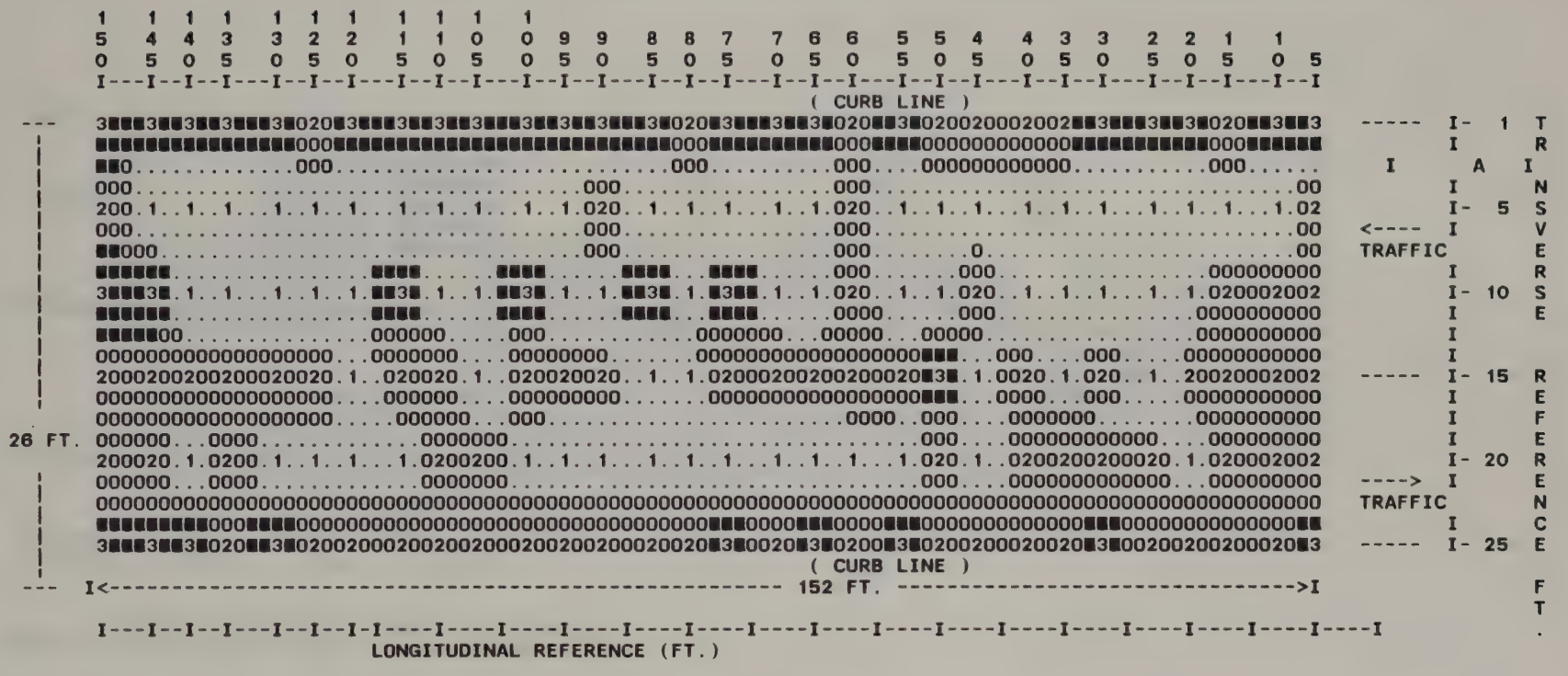
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1.00	4.01	94.99

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	.....	000000000	■■■■■■■■■■
	.....	000000000	■■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■■
	.....	000000000	■■■■■■■■■■
FREQ.	131	14	35

Figure 16. 1984 Corrosion Potential - Royston Bridge Membrane No. 10



WAVERLY RR BRIDGE

POTENTIAL DATA FOR 1984

DATA VALUE EXTREMES ARE 0.01 0.47

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	0.20	0.36
MAXIMUM	0.20	0.36	0.60

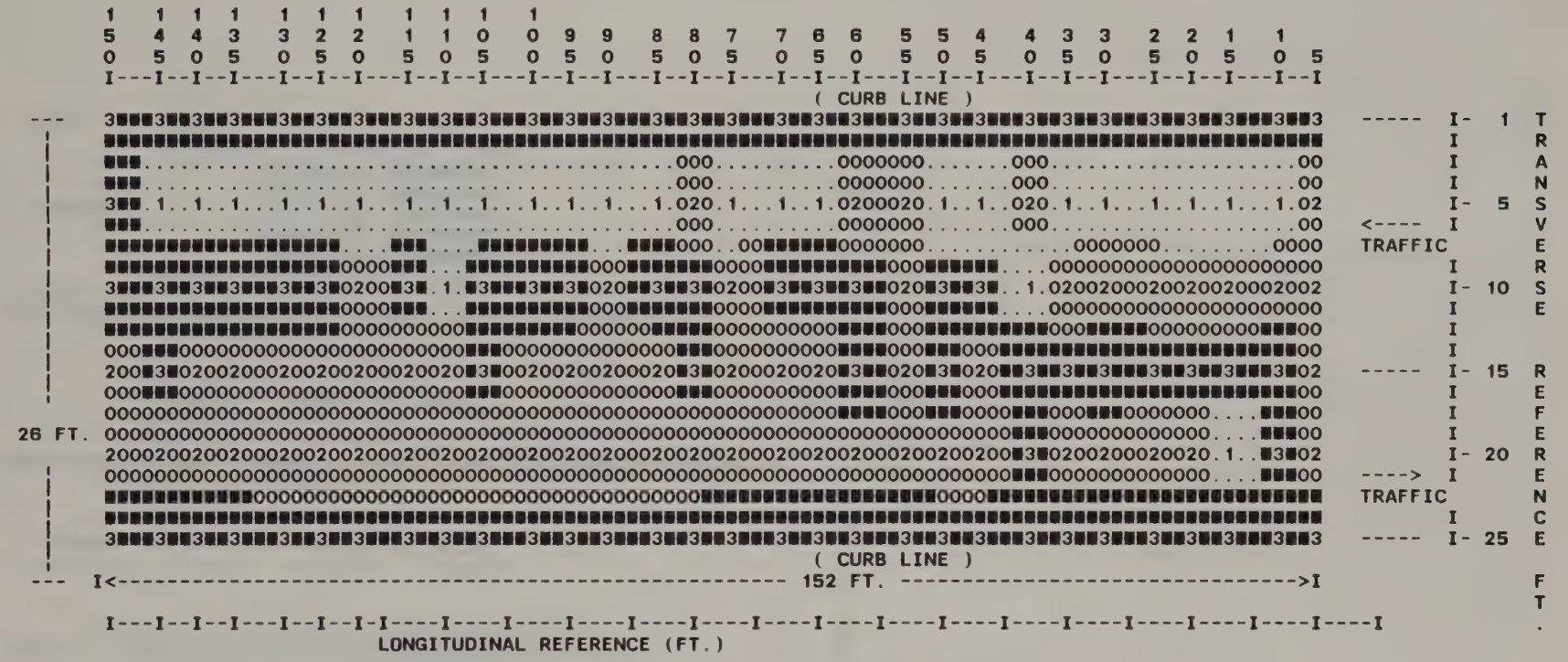
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

33.33 26.67 40.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
FREQ.	69	73	38

Figure 17. 1989 Corrosion Potential - Royston Bridge Membrane No. 10



TEST DATE 09/27/89.
CORROSION POTENTIAL
ROYSTON BRIDGE MEMBRANE NO. 10
IN SERVICE -- 13 YRS

BRIDGE DECK TEST SITE
WAVERLY RR BRIDGE
BIN 1023180

NORTH

WAVERLY RR BRIDGE

POTENTIAL DATA FOR 1989

DATA VALUE EXTREMES ARE 0.01 0.56

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	0.20	0.36
MAXIMUM	0.20	0.36	0.60

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

33.33	26.67	40.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
FREQ.	27	61	92

APPENDIX D

NEA-4000LT Membrane Waterproofing

ITEM - BRIDGE MEMBRANE WATERPROOFING SYSTEM
(PVC POLYMER, LT)

DESCRIPTION: This work shall consist of furnishing and applying a liquid, poly-vinyl chloride polymer waterproofing system. It shall include the preparation of concrete surfaces; the application of one coat of hot applied PVC polymer waterproofing and protective sheet as shown on the Contract Plans.

MATERIALS: The bridge membrane waterproofing system shall consist of the following materials:

PVC Polymer Waterproofing - Liquid polymer waterproofing material shall be one of the following:

1. NEA-4000 LT, as manufactured by POSH Chemical, Inc., Port Washington, N.Y.

or

2. Superseal-4000 LT, as manufactured by Superior Products Co., Oakland, CA.

or

3. WABO-4000 LT, as manufactured by Watson-Bowman Assoc., Inc., Buffalo, N.Y.

Protective Sheet - 65-lb. asphalt roofing paper, meeting the requirements of ASTM D-224, 65-lb. Grade.

Wire Mesh - for use over subdrainage openings shall be a ¼ inch mesh by 23 gauge, hot dipped galvanized cloth.

Note: Containers of PVC polymer waterproofing material shall be stored on the work site in such a manner as to prevent their exposure to direct sunlight and to temperatures exceeding 100°F.

CONSTRUCTION DETAILS:

A. Preparation of Concrete Structural Slab Surfaces:

Work shall not begin on new structural slabs until a minimum of 7 days after concrete placement.

All structural slab surfaces designated to receive liquid waterproofing materials, including vertical surfaces shall be prepared and cleaned as follows:

1. All loose material, including dirt, stones and gravel shall first be removed by vacuuming or blowing with compressed air.

2. The entire structural slab surface shall be sandblasted. Sandblast operations shall be done to the extent that excess laitance (surface film of concrete mortar), road oil, other bituminous based contaminants and foreign materials, including concrete during compounds and previous membrane treatments are removed. If necessary the blasting operation shall be supplemented by wire brushing or washing with water. At the completion of sandblasting operations, all blasting residue shall be removed by vacuuming or blowing with compressed air.

3. All surface projections, including exposed aggregate and other protrusions greater than ¼ inch in height shall be ground smooth or grouted smooth with cement or epoxy mortar. Sharp concrete edges shall be ground smooth. Potholes and spalled areas shall be patched with cement or epoxy mortar. Patching and grinding operations shall be done to the extent that the surface roughness of the structural slab does not exceed ¼ inch per foot. If grouting materials are used they shall be cured and surface dry prior to the application of PVC waterproofing material. Cement mortar mixes for use in grouting shall be approved by the Engineer prior to use. Epoxy mortar materials shall consist of epoxy material meeting the requirements of Material Specification 721-01, 721-02, or 721-03, and dry fine aggregate as approved by the Engineer.

4. If necessary, immediately preceding the application of the PVC waterproofing, surfaces to be waterproofed shall be re-cleaned of dust and other loose foreign material that may have accumulated, by vacuuming or blowing with compressed air.

B. Atmospheric Conditions:

Work shall not be done during wet weather conditions nor, when atmospheric conditions are such that unsatisfactory results will be produced. The Engineer shall be the sole determinant of favorable atmospheric conditions. No work shall be done when the concrete structural slab surface temperature is below 40°F or ambient temperatures are below 40°F. The concrete structural slab shall be surface dry at the time of application of the PVC waterproofing material.

C. Application of PVC Polymer Waterproofing Material:

After cleaning operations have been completed, surfaces to be waterproofed shall be coated with one coat of PVC polymer waterproofing material. The PVC waterproofing shall be hot applied at a minimum rate of 17.8 square feet per gallon (minimum wet film thickness of 90 mils) and at a temperature of from 275°F to 300°F. All concrete structural slab surfaces shall be surface dry at the time of application of waterproofing material.

The PVC waterproofing material, as supplied in its container, is ready for pouring into the heating vessel. The heating vessel shall be double-boiler, indirect-fired or oil-bath melter-applicator type kettle. Heating with direct flame shall not be allowed. Heating equipment shall be inspected and approved by the Engineer prior to use. When the application temperature (275-300°F) has been attained, the hot polymer material shall be poured directly onto the structural slab and spread at the specified application rate, using squeegees. Brushes and rollers may be used to supplement the squeegee operation.

The vertical faces of curbs, headers and scuppers shall be coated with hot PVC waterproofing and finished off in a neat line, to a height that will be at least 1 inch higher than the height of bituminous overlay. If necessary on the vertical face multi-coat applications shall be made to obtain the required film thickness (90 mils, min.).

The inside surfaces of sub-drainage outlets (weep tubes) shall be coated with hot PVC waterproofing to a depth of at least 1 inch. Immediately after placement of the waterproofing material, 5-inch square pieces of wire mesh shall be pressed into the wet coat of PVC over each sub-drainage opening.

The completed coat of waterproofing shall be free of large pinholes, craters and other placement defects. Pinholes and craters of 1/8 inch diameter and greater shall be corrected by "touching" up with hot PVC material or sealing with pre-cured pieces of PVC waterproofing. Pre-cured patch material is made by applying hot liquid PVC to a smooth, impervious surface (the lid or top of the PVC container is suitable) and allowing it to cure in a sheet form. Pieces of this sticky sheet may then be used to plug holes or patch the PVC membrane. Defects in the waterproofing of less than 1/8" diameter are self-sealing and shall not require repair.

Throughout the duration of work the Contractor shall protect all exposed areas of curbs, sidewalks, railings and other bridge appurtenances. Any damage or defacement resulting from the application of the PVC waterproofing shall be repaired to the satisfaction of the Engineer, at no cost to the State.

D. Application of Protective Sheet:

The protective sheet (65 lb. roofing paper) shall be placed over the PVC polymer waterproofing immediately after completion of the liquid waterproofing application, or a portion thereof, as directed by the Engineer.

The 65-lb. roofing paper shall be placed over all of the structural slab surface, except that it shall not be placed on the vertical faces of curbs, or headers or scuppers. At sub-drainage outlets, holes equal in size to

the outlet opening shall be cut in the roofing paper. The roofing shall not be placed in, or otherwise adhered to the inside surfaces of sub-drainage outlets.

The protective sheet shall be laid flat, without the necessity of adhesives, on the cured surface of PVC waterproofing. (Hot applied liquid PVC polymer waterproofing material will cure to a firm film within several minutes. The surface of the cured PVC will remain in a tacky or sticky condtion. The 65# roofing paper is to be applied directly to the sticky surface.) Rolls or sections of 65-lb. roofing paper shall be set in place by butting against the edges and ends of adjacent sheets. Gaps of up to ¼ inch between sheets are allowable. Overlapping of the protection sheet shall not be allowed.

The completed protection sheet shall be free of wrinkles, "fishmouths," entrapped air bubbles and other defects. Wrinkles and "fishmouths" shall be slit with a knife and laid flat. Entrapped air shall be removed by piercing the roofing paper with an ice pick or other suitable instrument. Care shall be taken not to puncture the underlying PVC membrane.

When the placement defects have been corrected, the entire surface of roofing paper shall be rolled with a 100-200 pound hand roller. If, after rolling, additional air bubbles or other defects are evident they shall be corrected.

Finally, when the placement and rolling of the roofing paper is complete, a bead of hot PVC polymer material shall be run along the intersection where the vertical faces of curbs, headers and scuppers meet the roofing paper. The bead shall be placed such that the void between the roofing paper and applied membrane is filled with polymer to prevent the intrusion of water.

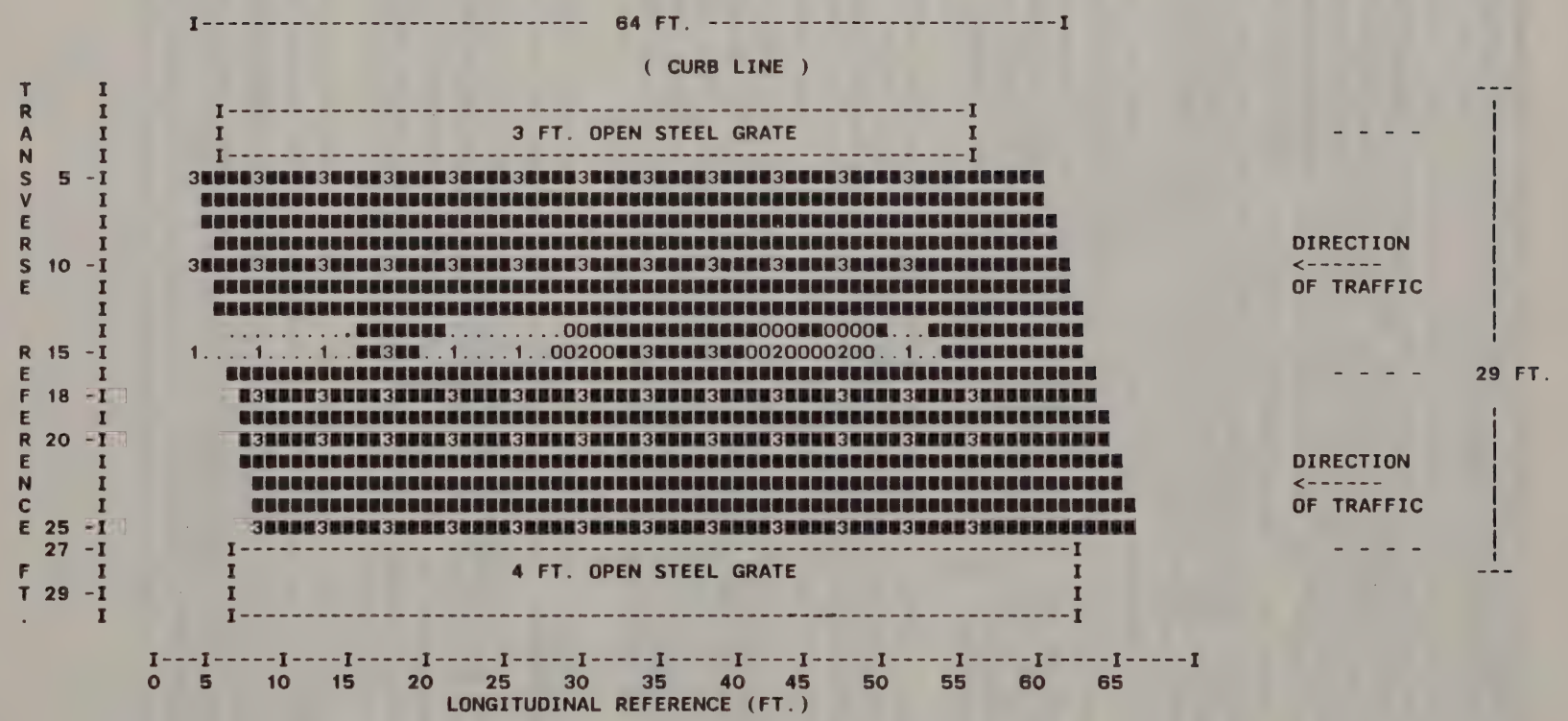
METHOD OF MEASUREMENT:

The work shall be measured as the number of square feet of actual horizontal surface area of the structural slab covered with the complete membrane waterproofing system. No separate measurement of the vertical faces of curbs, headers and scuppers or for the inside surfaces of sub-drainage outlets shall be made.

BASIS OF PAYMENT:

The unit price bid per square foot for this item shall include the cost of furnishing all labor, materials (including wire mesh) and equipment necessary to complete the work.

Figure 18. 1984 Electrical Resistance - NEA 4000LT - Span 2



COHOCTON RIVER BRIDGE SPAN 2

ELECTRICAL RESISTANCE DC DATA FOR 1984

DATA VALUE EXTREMES ARE 6.00 9999.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	100.00	501.00
MAXIMUM	100.00	501.00	10000.00

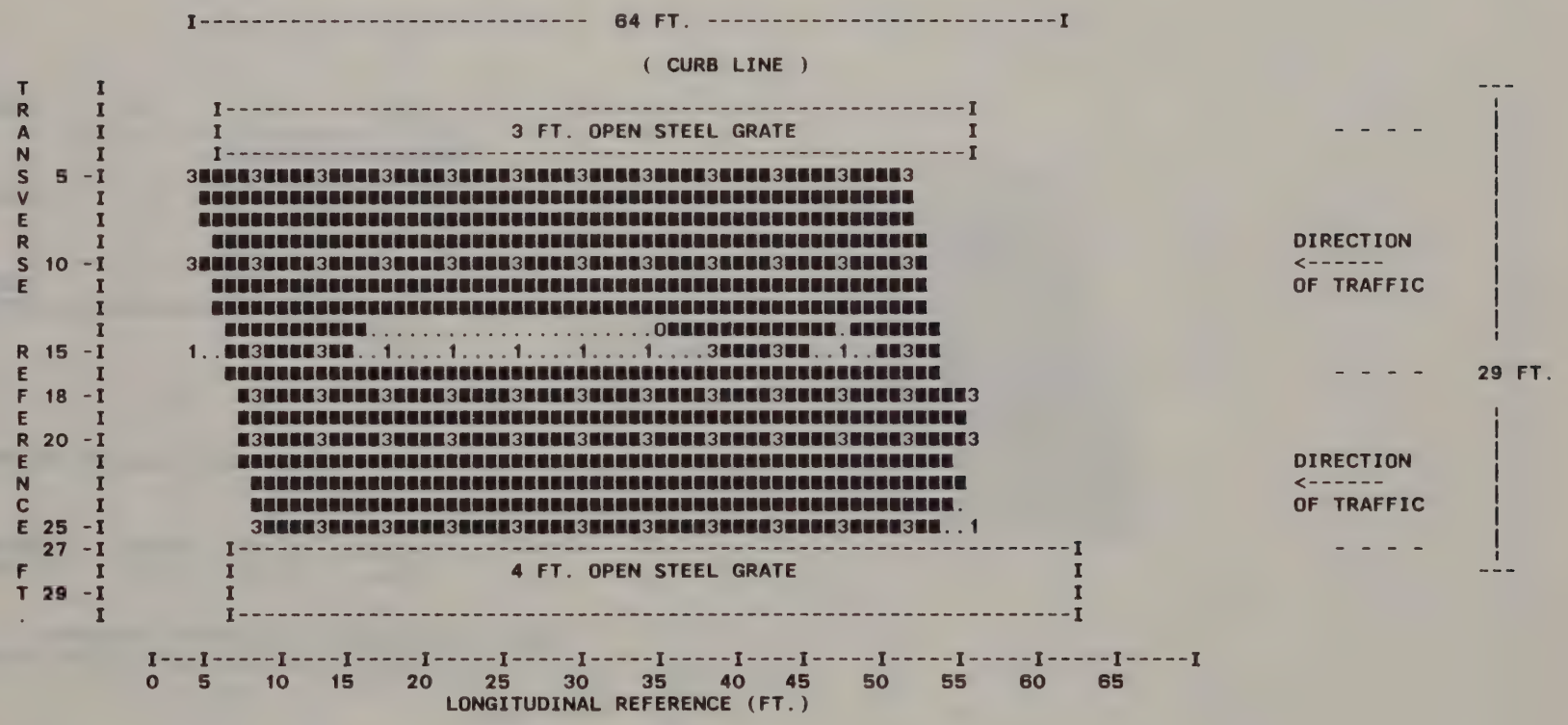
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

	1.00	4.01	94.99

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
FREQ.	6	3	63

Figure 19. 1984 Electrical Resistance - NEA 4000LT - Span 5



NORTH

TEST DATE 10/02/84.
ELECTRICAL RESISTANCE DC
NEA 4000-LT
IN SERVICE - 8 YEARS

BRIDGE DECK TEST SITE
COHOCTON RIVER BRIDGE - SPAN 5
BIN 1011160

COHOCTON RIVER BRIDGE SPAN 5

ELECTRICAL RESISTANCE DC DATA FOR 1984

DATA VALUE EXTREMES ARE 0.00 9999.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	100.00	501.00
MAXIMUM	100.00	501.00	10000.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1.00 4.01 94.99

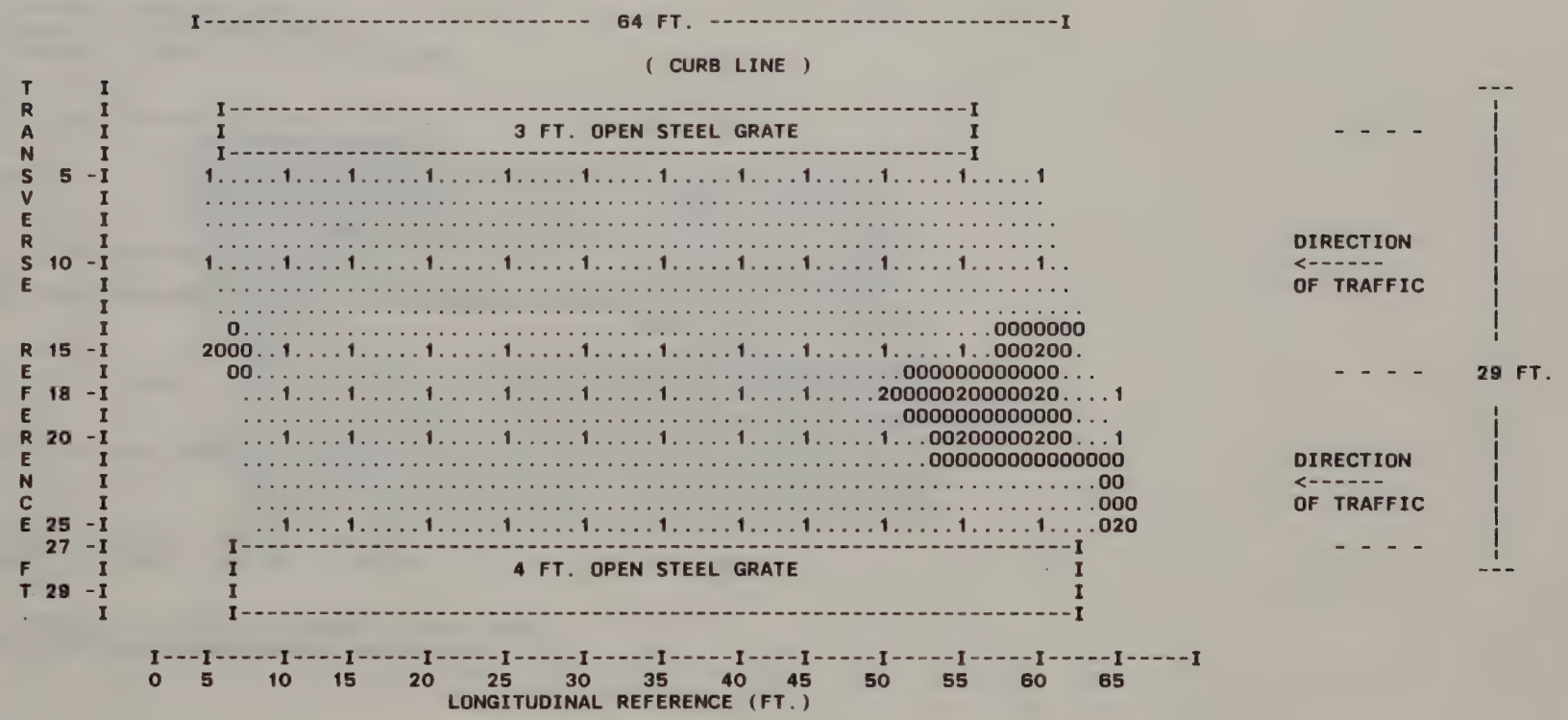
FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
FREQ.	8	0	64

0.1 MINUTES ELAPSED TIME FOR HISTOGRAM
0.0 MINUTES TOTAL PROCESSOR TIME
0.1 MINUTES TOTAL IO TIME

TIME OF DAY = 15/11

Figure 20. 1984 Corrosion Potential - NEA 4000LT - Span 2



NORTH

TEST DATE 10/02/84.
CORROSION POTENTIAL
NEA 4000-LT
IN SERVICE - 8 YEARS

BRIDGE DECK TEST SITE
COHOCTON RIVER BRIDGE - SPAN 2
BIN 1011160

COHOCTON RIVER BRIDGE SPAN 2

POTENTIAL DATA FOR 1984

DATA VALUE EXTREMES ARE 0.01 0.28

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	0.20	0.36
MAXIMUM	0.20	0.36	0.60

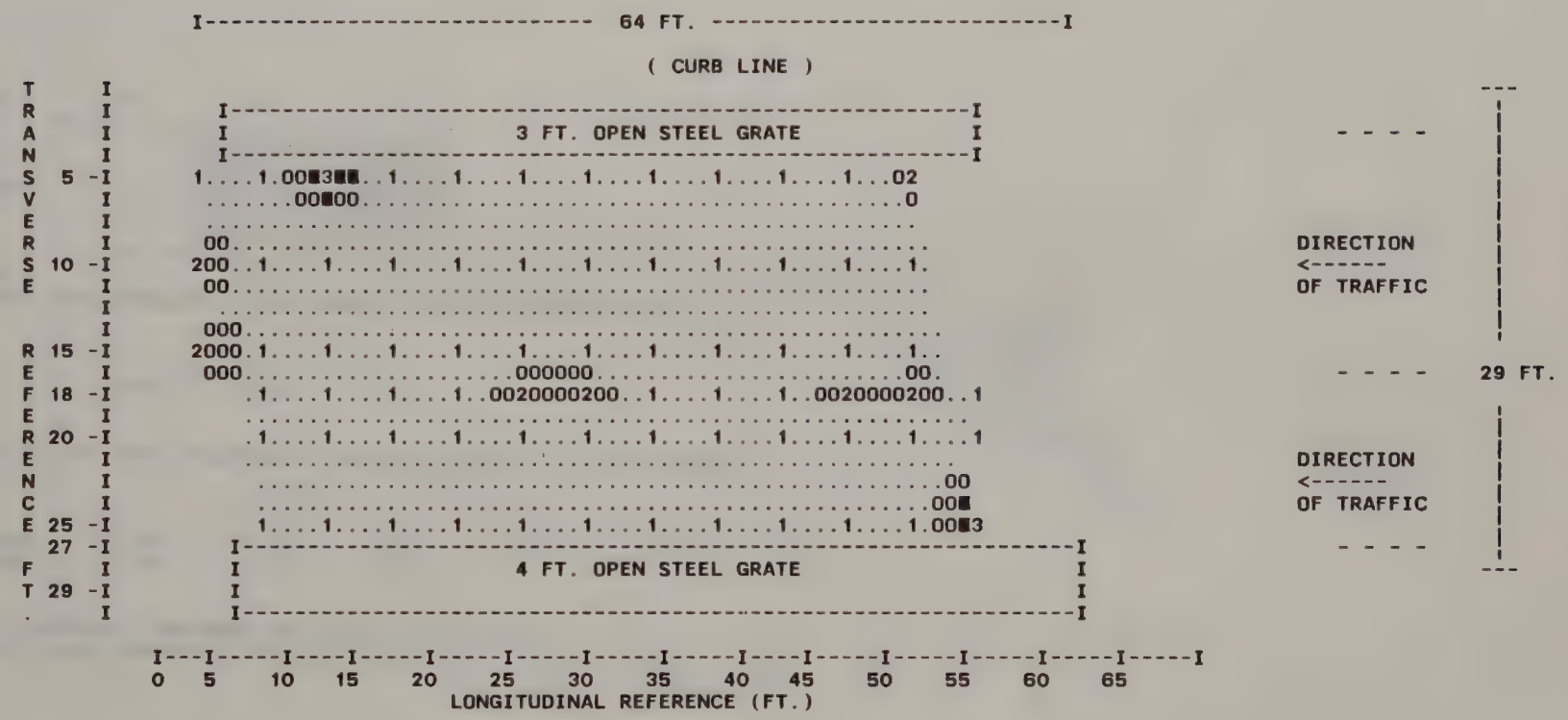
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

33.33 26.67 40.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
FREQ.	64	8	0

Figure 21. 1984 Corrosion Potential - NEA 4000LT - Span 5



NORTH

TEST DATE 10/02/84.
CORROSION POTENTIAL
NEA 4000-LT
IN SERVICE - 8 YEARS

BRIDGE DECK TEST SITE
COHOCTON RIVER BRIDGE - SPAN 5
BIN 1011160

COHOCTON RIVER BRIDGE SPAN 5

POTENTIAL DATA FOR 1984

DATA VALUE EXTREMES ARE 0.01 0.47

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	0.20	0.36
MAXIMUM	0.20	0.36	0.60

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

33.33 26.67 40.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	.....	000000000	■■■■■■■■■■
	.....	000000000	■■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■■
	.....	000000000	■■■■■■■■■■
FREQ.	63	7	2

APPENDIX E

Bituminous Epoxy Membrane Waterproofing (Two-Coat Application)

ITEM - BRIDGE BITUMINOUS EPOXY MEMBRANE WATERPROOFING SYSTEM (TWO COAT APPLICATION).

DESCRIPTION: This work shall consist of furnishing and applying a bituminous epoxy waterproofing system. It shall include the preparation of concrete surfaces; the application of two coats of bituminous epoxy protective coating and the application of coarse aggregate as shown on the contract plans.

MATERIALS: The bituminous epoxy membrane waterproofing system shall consist of materials meeting the requirements of the following subsections of Section 700 - Materials.

Bituminous Epoxy Protective Coating	717-02
Coarse Aggregate	703-02

Wire mesh, for use over sub-drainage openings, shall be a ¼" mesh by 23 gauge, hot dipped galvanized cloth.

CONSTRUCTION DETAILS:

A. Preparation of Concrete Structural Slab Surfaces:

Work shall not begin on new structural slabs until a minimum of 7 days after concrete placement.

All structural slab surfaces to be waterproofed, including vertical surfaces shall be prepared and cleaned as follows:

1. All loose material, including dirt, stones, gravel and concrete laitance shall be first removed by vacuuming or blowing with compressed air.

2. The entire structural slab surface shall be sandblasted. Sandblast operations shall be done to the extent that excess laitance (surface film of concrete mortar), road oil, other bituminous based contaminants and other foreign materials, including concrete curing compounds and previous membrane treatments are removed. If necessary, the blasting operation shall be supplemented by wire brushing or washing with water. At the completion of sandblasting operations, all blasting residue shall be removed by vacuuming or blowing with compressed air.

3. All surface projections, including exposed aggregate and other protrusions greater than ¼ inch in height shall be ground smooth or grouted smooth with cement or epoxy mortar. Sharp concrete edges shall be ground smooth. Potholes and spalled areas shall be patched with cement or epoxy mortar. Patching and grinding operations shall be done to the extent that the surface roughness of the structural slab does not exceed ¼ inch per foot. If grouting materials are used they shall be cured and surface dry prior to the application of bituminous epoxy protective coating. Cement mortar mixes for use in grouting shall be approved by the Engineer prior to use. Epoxy mortar materials shall consist of epoxy material meeting the requirements of Material Specification 717-02, 721-01, 721-02, or 721-03,

and dry fine aggregate as approved by the Engineer.

4. If necessary, immediately preceding the application of bituminous epoxy protective coating, surfaces to be waterproofed shall be re-cleaned of dust and other loose foreign material that may have accumulated by vacuuming or blowing with compressed air.

B. Atmospheric Conditions:

Work shall not be done during wet weather conditions nor when atmospheric conditions are such that unsatisfactory results will be produced. The Engineer shall be the sole determinate of favorable atmospheric conditions. No work shall be done when the concrete structural slab surface temperature is below 50°F or ambient temperatures are below 50°F or when the relative humidity is greater than 85%. The concrete structural slab shall be surface dry at the time of application of bituminous epoxy protective coating.

C. Application of Bituminous Epoxy Membrane Waterproofing System:

After cleaning operations have been completed, surfaces to be waterproofed shall be covered with two coats of bituminous epoxy protective coating and one application of coarse aggregate.

Concrete structural slab or previously coated surfaces shall be surface dry at the time of application of bituminous epoxy protective coating.

If necessary, the Contractor shall protect uncured coats of bituminous epoxy protective coating against rain or other detrimental elements. Protection shall be provided for the time period required for the bituminous epoxy to field cure.

For purposes of this specification, field cure is determined as the time required for the bituminous epoxy to cure to a firm, hard state, such that no movement of the film or damage occurs due to foot traffic.

Each coat of bituminous epoxy protective coating shall be applied at the rate of 30-35 square feet per gallon. The bituminous epoxy shall be thoroughly mixed prior to use. Mixing shall be done with mechanical mixers or hand mixed, using clean paddles or other suitable instruments. Care shall be taken to minimize the introduction of air bubbles in the epoxy during mixing. The bituminous epoxy shall be applied without dilution. The first coat shall be applied and thoroughly worked into the structural slab surface by the use of brushes or rollers or squeeges or a combination of these methods. Spray application of the first coat of bituminous epoxy shall not be allowed. The second coat may be applied by airless spray or any of the preceding methods.

The first coat of bituminous epoxy shall be applied and allowed to obtain a field cure prior to the application of the second coat. Coarse aggregate

shall not be spread in the first coat. The appearance of bubbles in the bituminous epoxy is normal, due to out-gassing of air and moisture in the concrete. When the field cure has been obtained, bubbles in the first coat shall be broken as much as possible with squeeges or brooms. Unless otherwise directed by the Engineer, it shall not be necessary to repair the areas where bubbles have been broken.

The second coat of bituminous epoxy shall be placed as soon as possible after the first coat has field-cured. In any event the second coat shall be applied within 12 hours after placement of the first coat. If the second coat has not been applied within the 12-hour time period the dried surface of the first coat shall be roughed-up by sandblasting (brush-off blasting) and the sandblasting residue removed. Sandblasting and cleaning shall be at the Contractor's expense. Coarse aggregate shall be applied immediately after the application of the second coat of bituminous epoxy. The aggregate shall be spread while the epoxy surface is still wet and before any substantial degree of cure has been obtained. The primary size of coarse aggregate shall be No. 1, except that material passing the No. 200 sieve shall not exceed 0.5%. The coarse aggregate shall be surface dry and shall be spread on the wet bituminous surface at a rate of between 6 to 9 pounds per square yard (0.67 to 1.0 lbs. per square ft.). The pictorial standards of the Materials Bureau shall be used to visually define the application rate of aggregate.

The vertical faces of curbs, headers and scuppers shall be coated with two coats of bituminous epoxy and finished off in a neat line, to a height that will be at least 1 inch higher than the height of bituminous overlay. To seal the interface, if vertical faces are coated before or after the general application of a coat of bituminous epoxy on the horizontal deck, the coating shall extend down the vertical face and onto the horizontal structural slab or bituminous membrane for a minimum of 2 inches, as applicable. Coarse aggregate shall not be applied to vertical surfaces.

The inside surfaces of sub-drainage outlets (weep tubes) shall be coated with two coats of bituminous epoxy to a depth of at least 1 inch. Immediately after placement of the second coat, 5-inch square pieces of wire mesh shall be pressed into the wet epoxy over each sub-drainage opening. The wire mesh shall be placed before the coarse aggregate is spread on the second coat of bituminous epoxy. Coarse aggregate shall not be applied to the inside surfaces of sub-drainage outlets.

The completed membrane waterproofing system shall be free of large air bubbles and other placement defects. These shall be corrected as directed by and to the satisfaction of the Engineer. Bubbles of 1 inch diameter and greater shall be vented by piercing with an ice pick or other suitable instrument and expelling the air. Vented bubbles in the second coat of bituminous epoxy shall be sealed against water intrusion by "touching-up" with bituminous epoxy.

Throughout the duration of work the Contractor shall protect all exposed areas

of curbs, sidewalks, railings and other bridge appurtances. Any damage or defacement resulting from the application of the membrane system shall be repaired to the satisfaction of the Engineer, at no cost to the State.

METHOD OF MEASUREMENT:

The work shall be measured as the number of square feet of actual horizontal surface area covered with the complete membrane waterproofing system. No separate measurement for the vertical faces of curbs, headers and scuppers or the inside surfaces of sub-drainage outlets shall be made.

BASIS OF PAYMENT:

The unit price bid per square foot for this item, shall include the cost of furnishing all labor, materials (including wire mesh) and equipment necessary to complete the work.

717-02 BITUMINOUS EPOXY PROTECTIVE COATING

SCOPE. This specification covers the material requirements of a flexible bituminous epoxy protective coating system. This material is used as a protective membrane on Portland cement concrete structural decks with bituminous concrete wearing courses, and with aggregate as a mortar to repair structural decks which are to receive the protective membrane. This material should not be applied at temperatures below 50°F.

GENERAL. The bituminous epoxy protective coating system shall be a one coat, two component (1:1 ratio by volume), flexibilized, thermo-setting system consisting of a modified epoxy resin, Component A, and a curing agent, Component B.

MATERIAL REQUIREMENTS.

Characteristics of Component A. Component A shall consist of a modified epoxy resin, free of contaminants and shall exhibit the following characteristics.

Property	ASTM Test Method	Requirements Min.	Max.
Viscosity at 75±2°F,cps.	-	-	3000
Epoxide Equivalent	D-1652	225	265
Ash Content, % by Weight	D-482	-	0.2
Volatile Content, mls, distillate	D-1078	-	3.0

Characteristics of Component B. Component B shall be the curing agent for the modified epoxy resin (Component A) and shall consist of a bitumen which has been especially treated with a modified aliphatic polyamine to produce the required properties. It shall exhibit the following characteristics:

Property	ASTM Test Method	Requirements Min.	Max.
Viscosity at 75±2°F,cps.	-	400	1100
Ash Content, % by Weight	D-482	-	0.5
Volatile Content, mls distillate, below 350°F.	D-1078	-	3.0

Pot Life and Cure Requirements. A mixture of Components A and B, prepared in the ratio of 1:1 by volume, shall exhibit the following characteristics:

Property	ASTM Test Method	Requirements Min.	Max.
Color	-	Black	-
Pot Life, minutes	-	10	45
Shore "D" Hardness at 75±2°F.,points	D-2240	35/10	55/10

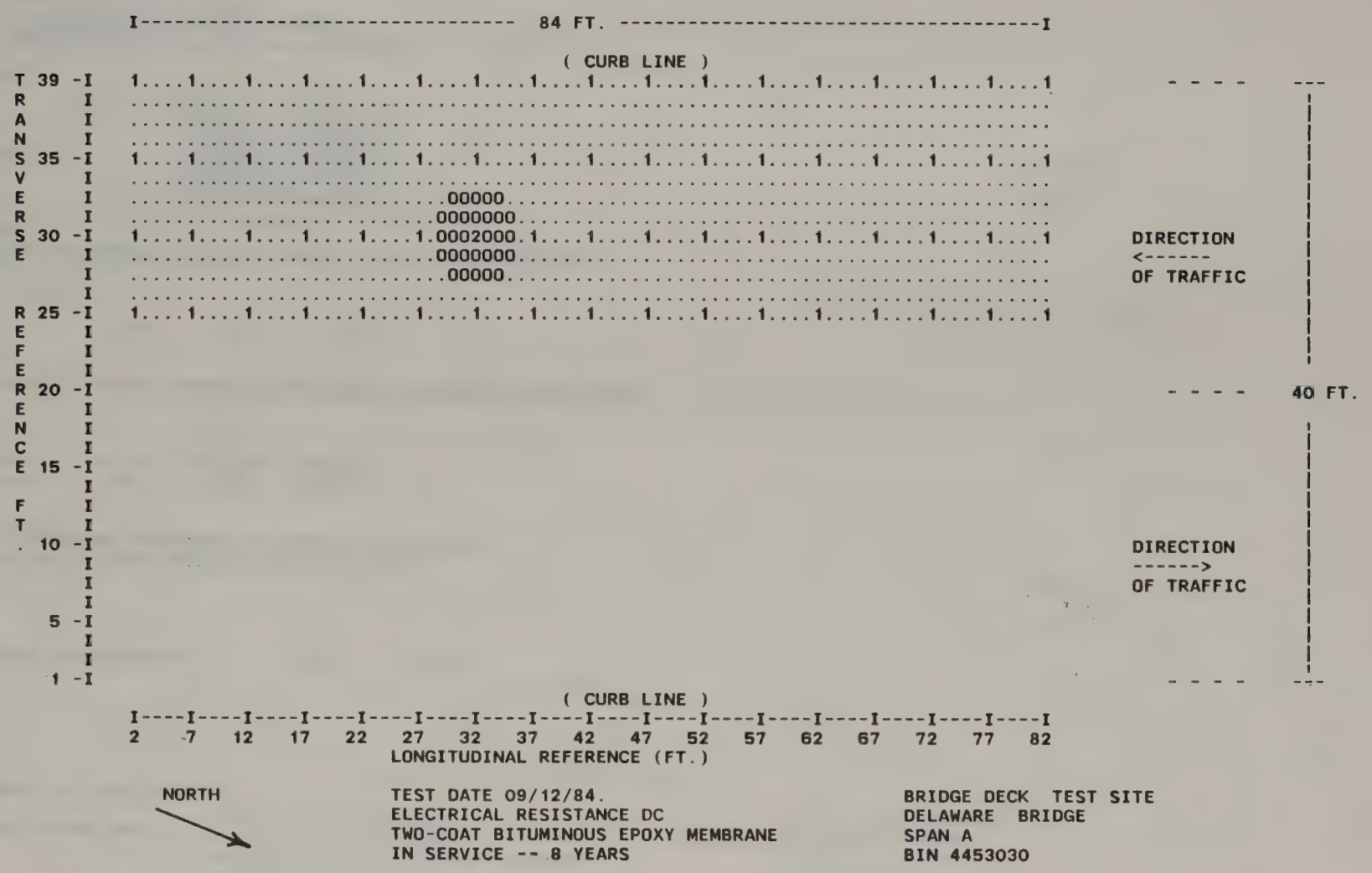
The chemical composition of the mixed components shall be so controlled that cure of a 70 mil thick film when applied to a concrete deck will be accomplished within the time and under the conditions indicated below:

Ambient Air and Deck Temperature, °F	Maximum Cure Time, Hrs. Night	Day
50	6	5
70	5	4
90	3	2.5

Cured Properties of Test Casting. A test casting of Components A and B in the ratio of 1:1 by volume shall be prepared in a mold open to the atmosphere on the top surface. The thickness of the casting shall be 1/8"±1/32". The casting shall be allowed to cure for 7 days at 75±2°F and 50% relative humidity. The casting may be removed from the cell after 24 hours. Completely cured casting shall exhibit the following characteristics:

Property	ASTM Test Method	Requirements Min.	Max.
Water Absorption 7 days immersion at 75±2°F, % by wt.	D-570 (2" disc)	-	0.6
Tensile Strength at 75±2°F, ("C" die, as in ASTM D-412, except that the thickness shall be 1/8"±1/32".), psi	D-638 test rate 0.2in/min.	500	-
Tensile Elongation at 75±2°F percent	D-638	50	-

Figure 22. 1984 Electrical Resistance - 2 Coat Bituminous Epoxy - Span A



DELAWARE BRIDGE SPAN A

RESISTANCE DC DATA FOR 1984

DATA VALUE EXTREMES ARE 1.00 250.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	100.00	501.00
MAXIMUM	100.00	501.00	10000.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1.00 4.01 94.99

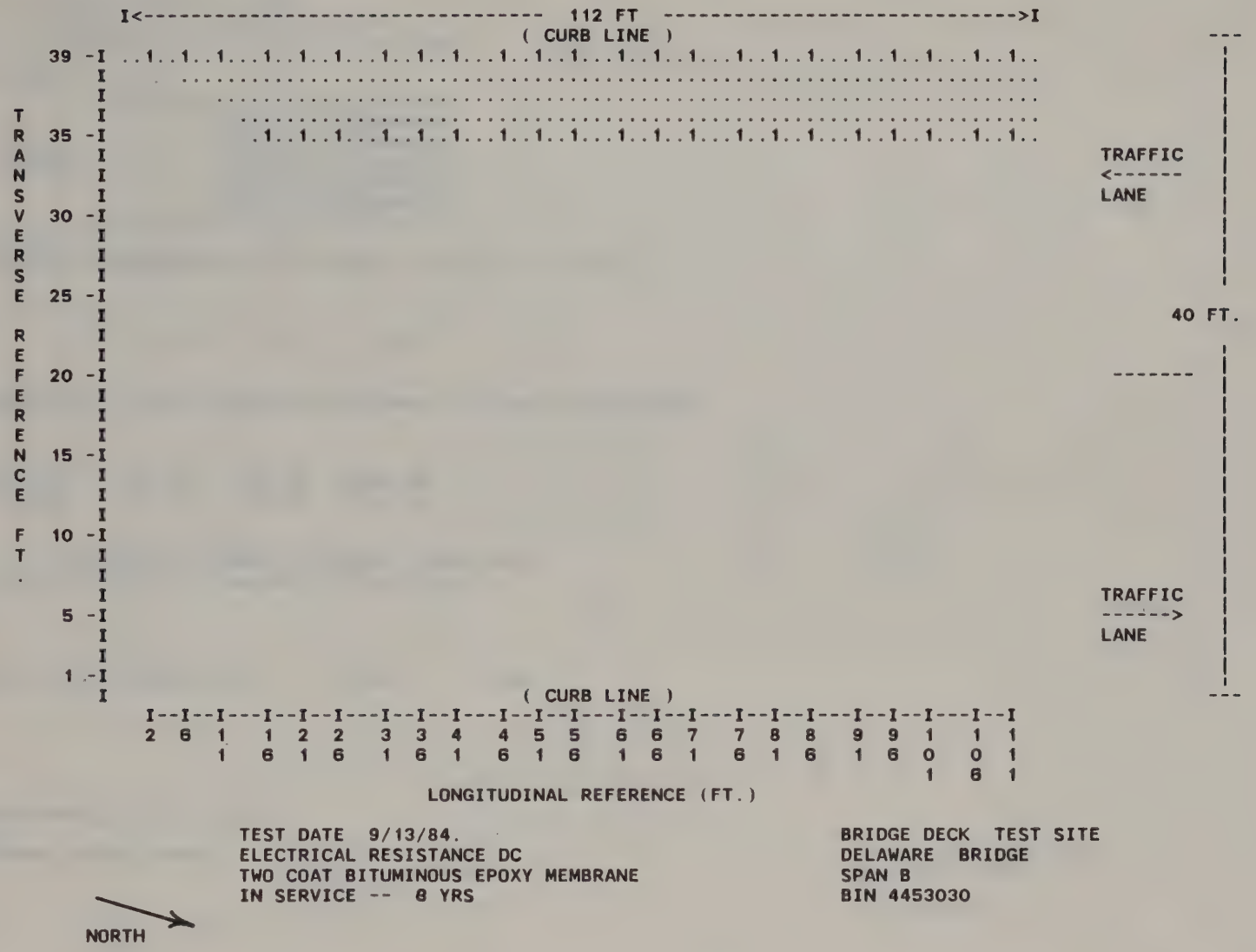
FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
FREQ.	87	1	0

0.1 MINUTES ELAPSED TIME FOR HISTOGRAM
0.0 MINUTES TOTAL PROCESSOR TIME
0.1 MINUTES TOTAL IO TIME

TIME OF DAY = 14/59

Figure 23. 1984 Electrical Resistance - 2 Coat Bituminous Epoxy - Span B



DELAWARE BRIDGE SPBN B

RESISTANCE DC DATA FOR 1984

DATA VALUE EXTREMES ARE 1.00 5.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	100.00	501.00
MAXIMUM	100.00	501.00	10000.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1.00	4.01	94.99

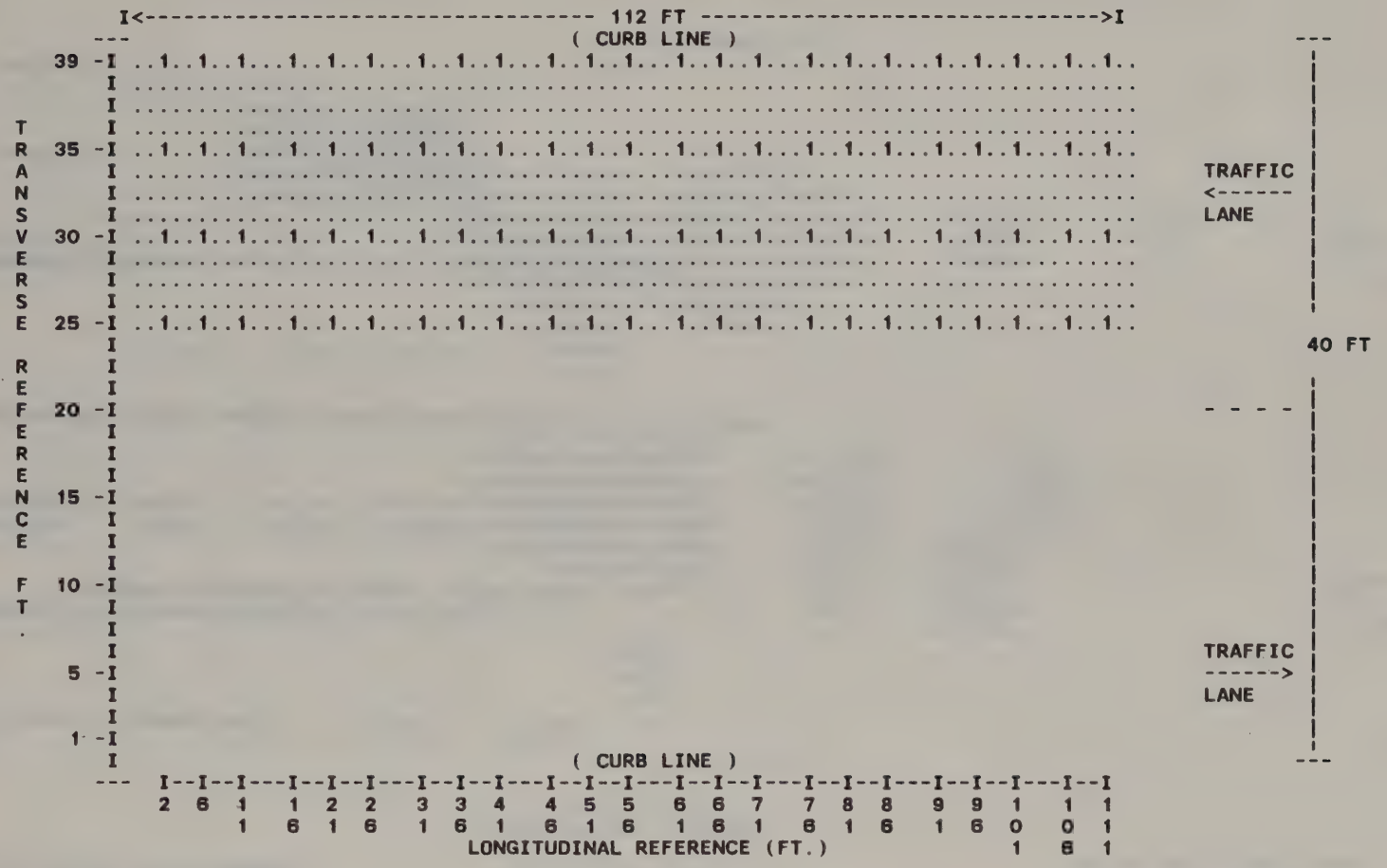
FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	.....	000000000	■■■■■■■■■■
	.....	000000000	■■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■■
	.....	000000000	■■■■■■■■■■
FREQ.	43	0	0

0.4 MINUTES ELAPSED TIME FOR HISTOGRAM
0.0 MINUTES TOTAL PROCESSOR TIME
0.2 MINUTES TOTAL IO TIME

TIME OF DAY = 15/47

Figure 24. 1984 Electrical Resistance - No Membrane - Span C



DELAWARE BRIDGE SPAN C

RESISTANCE DC DATA FOR 1984

DATA VALUE EXTREMES ARE 1.00 35.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	100.00	501.00
MAXIMUM	100.00	501.00	10000.00

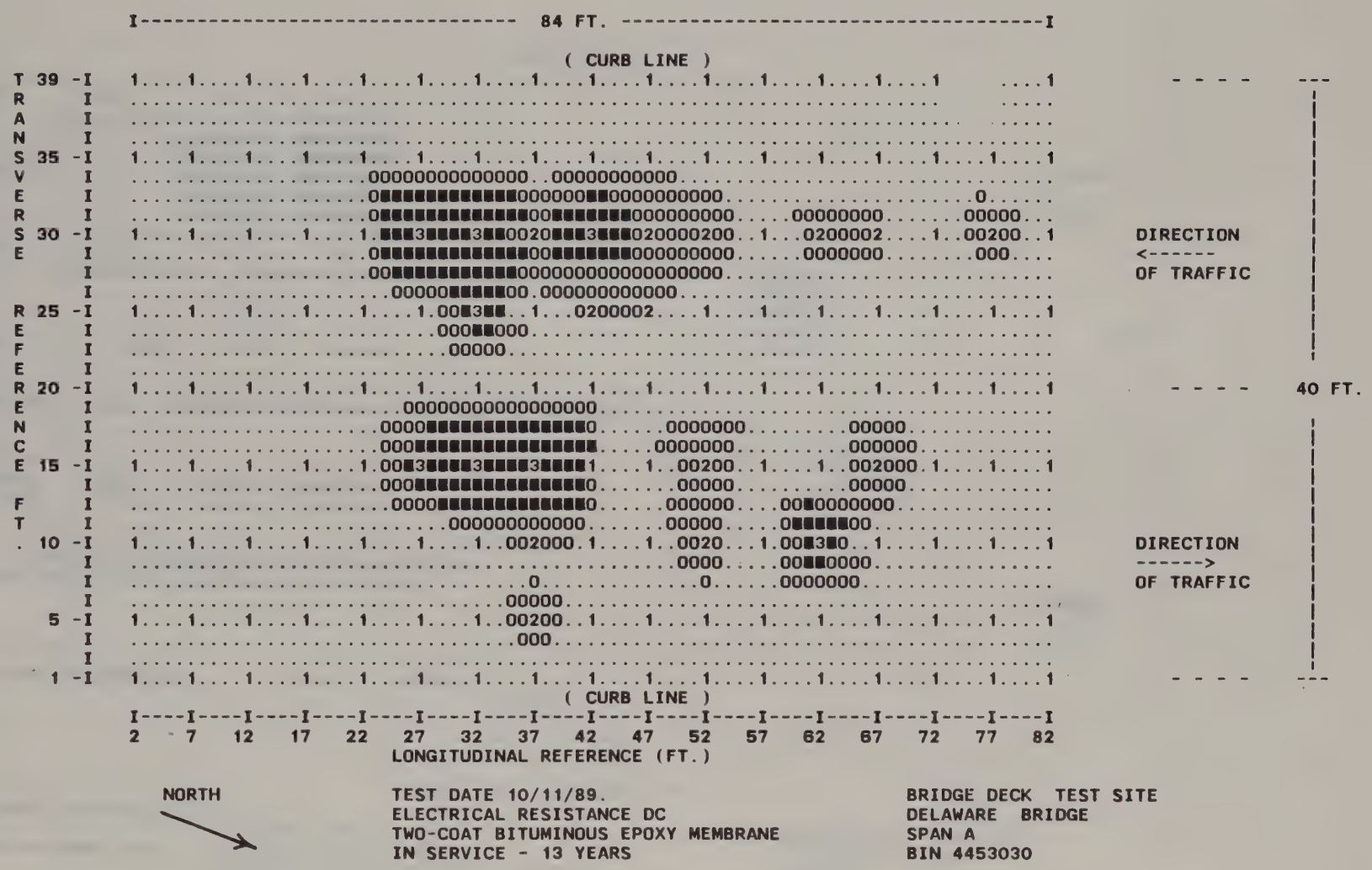
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1.00	4.01	94.99

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
SYMBOLS	.....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
FREQ.	92	0	0

Figure 25. 1989 Electrical Resistance - 2 Coat Bituminous Epoxy - Span A



DELAWARE BRIDGE SPAN A

RESISTANCE DC DATA FOR 1989

DATA VALUE EXTREMES ARE 5.00 5000.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	100.00	501.00
MAXIMUM	100.00	501.00	10000.00

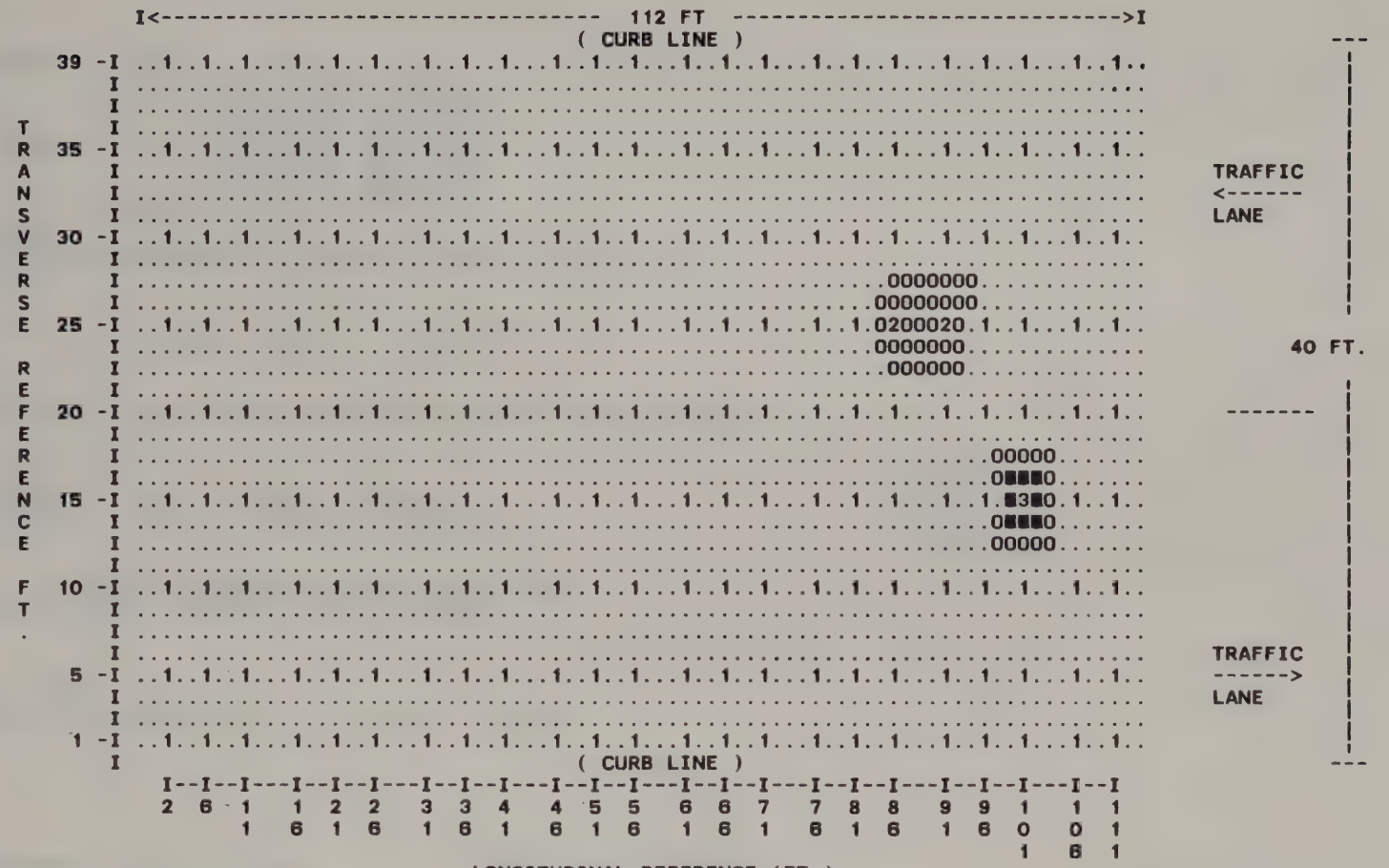
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1.00 4.01 94.99

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
		==========	==========
		 000000000	■■■■■■■■■■
		 000000000	■■■■■■■■■■
SYMBOLS		....1.... 000020000	■■■■3■■■■
		 000000000	■■■■■■■■■■
		 000000000	■■■■■■■■■■
		==========	==========
FREQ.	132	13	8

Figure 26. 1989 Electrical Resistance - 2 Coat Bituminous Epoxy - Span B



DELAWARE BRIDGE SPBN B

RESISTANCE DC DATA FOR 1989

DATA VALUE EXTREMES ARE 0.00 800.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	100.00	501.00
MAXIMUM	100.00	501.00	10000.00

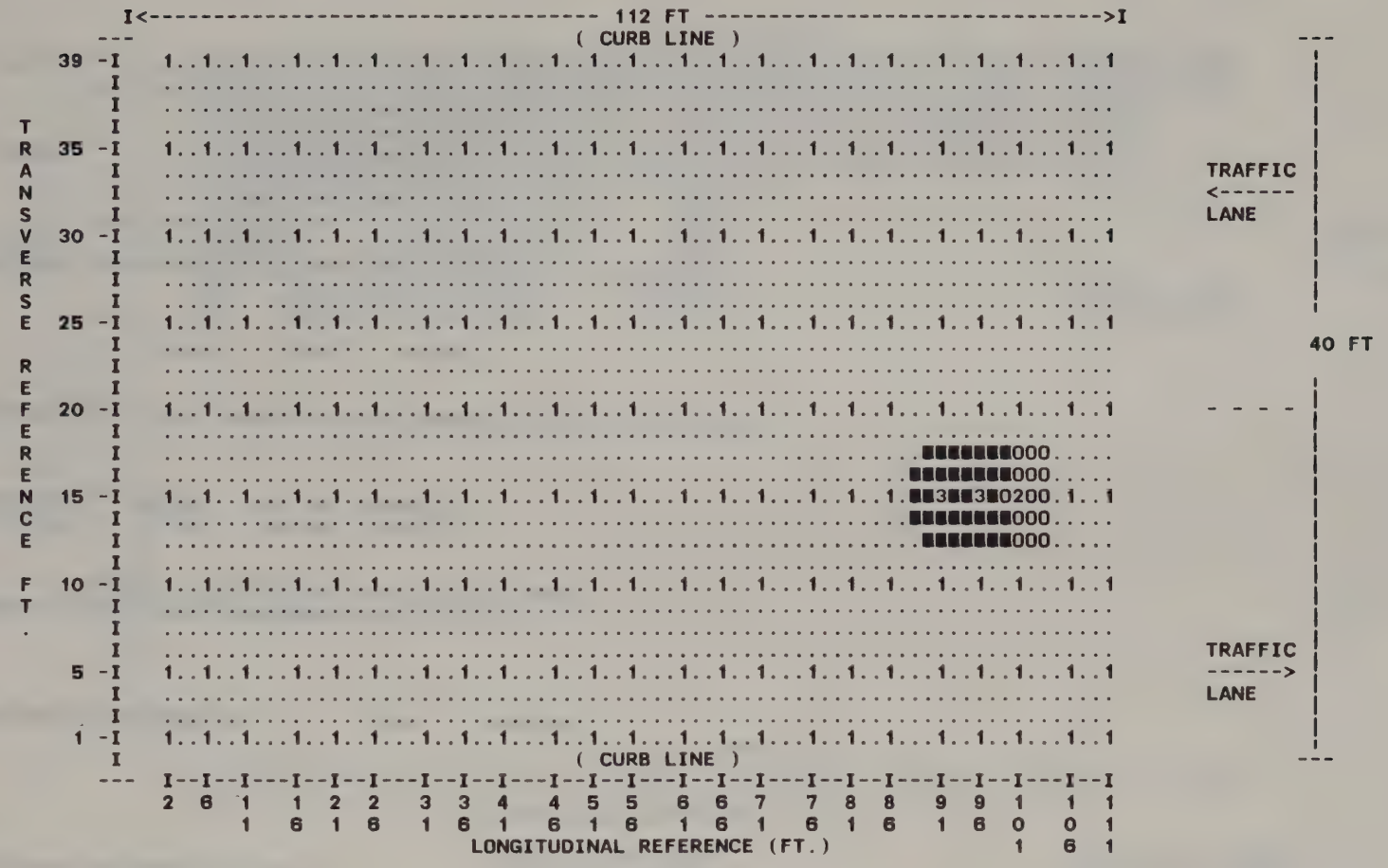
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1.00	4.01	94.99

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
FREQ.	204	2	1

Figure 27. 1989 Electrical Resistance - No Membrane - Span C



DELAWARE BRIDGE SPAN C

RESISTANCE DC DATA FOR 1989

DATA VALUE EXTREMES ARE 3.00 8000.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	100.00	501.00
MAXIMUM	100.00	501.00	10000.00

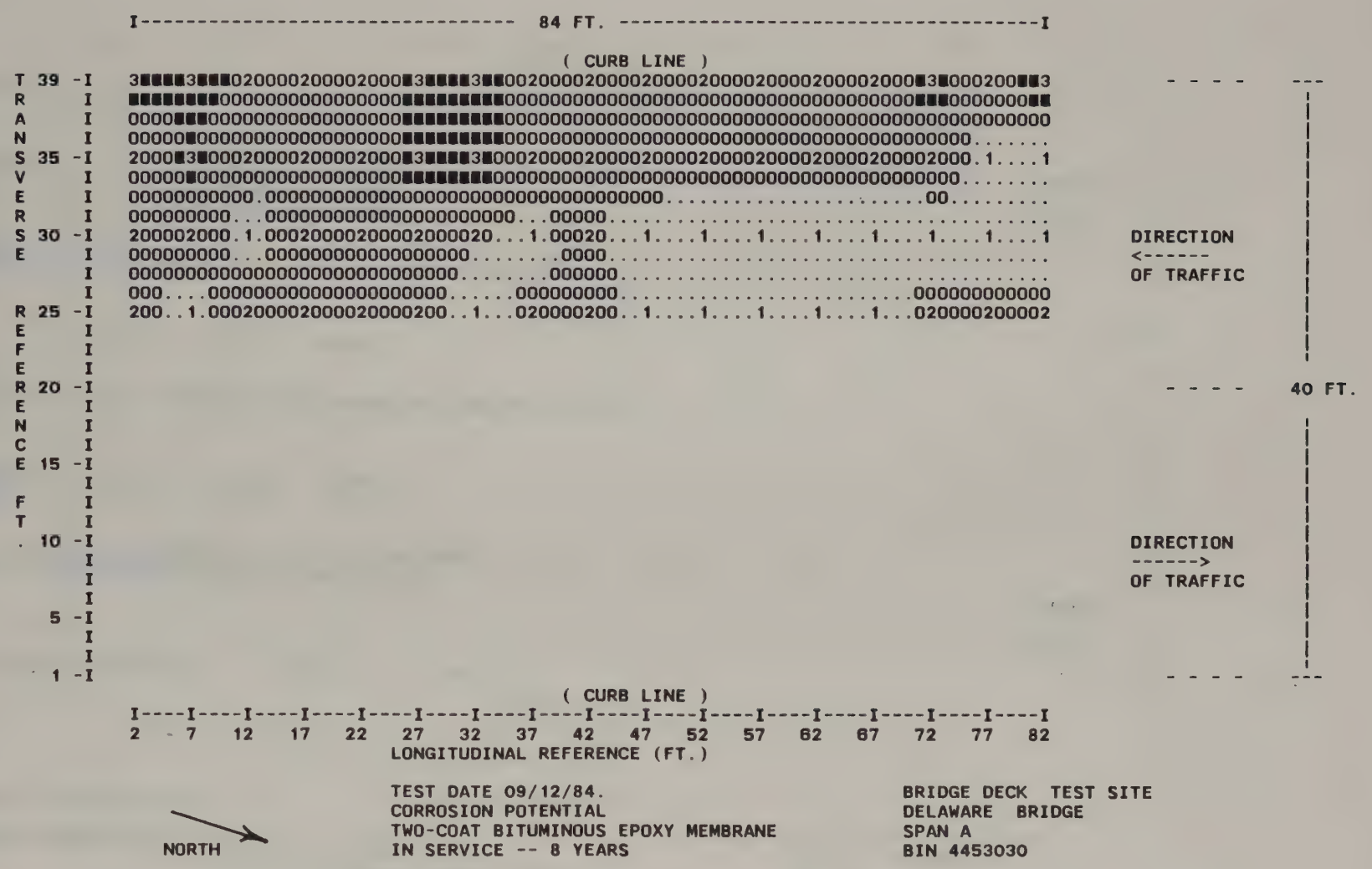
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1.00 4.01 94.99

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
FREQ.	204	1	2

Figure 28. 1984 Corrosion Potential - 2 Coat Bituminous Epoxy - Span A



DELAWARE BRIDGE SPAN A

POTENTIAL DATA FOR 1984

DATA VALUE EXTREMES ARE 0.11 0.42

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	0.20	0.36
MAXIMUM	0.20	0.36	0.60

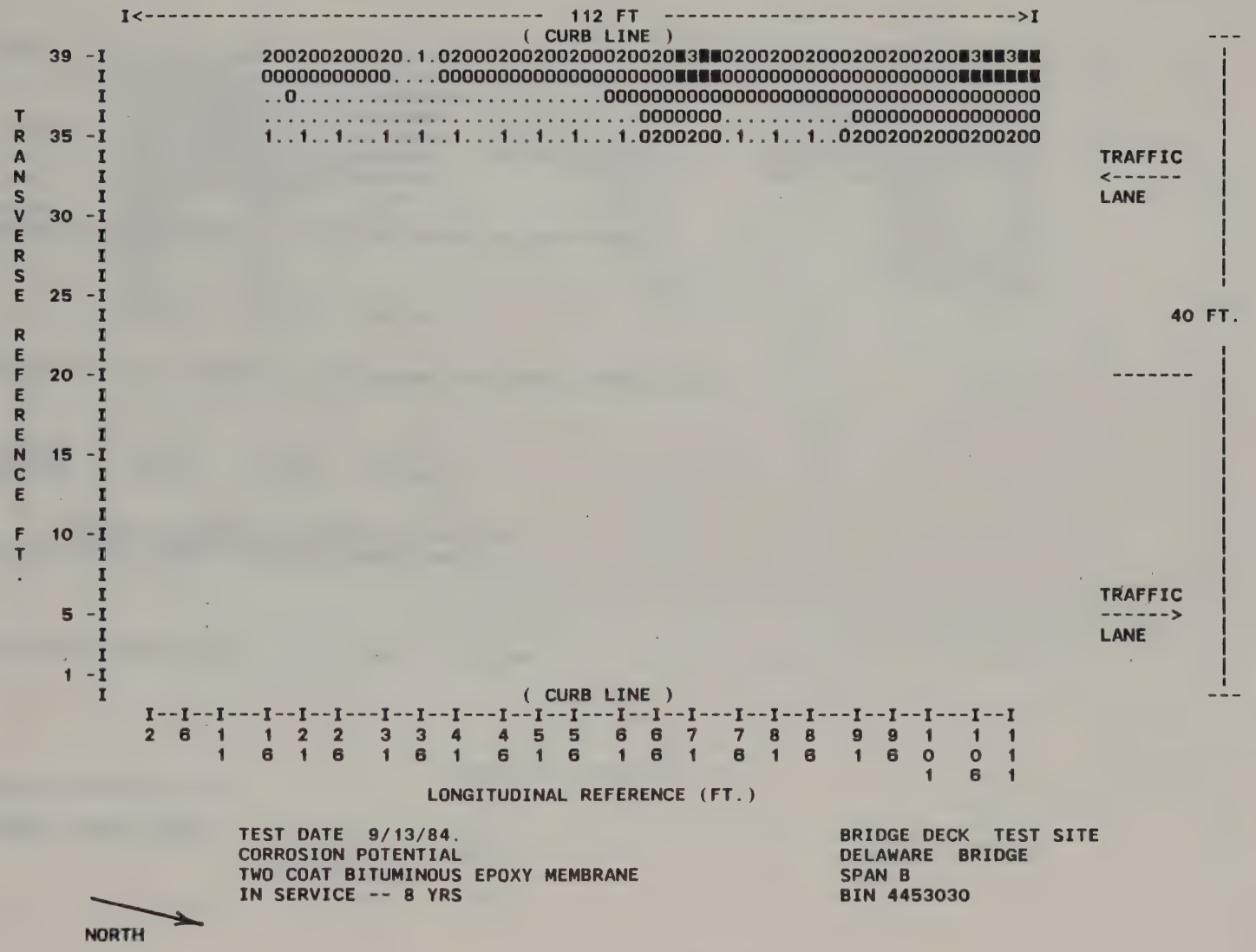
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

33.33 26.67 40.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
FREQ.	19	40	9

Figure 29. 1984 Corrosion Potential - 2 Coat Bituminous Epoxy - Span B



DELAWARE BRIDGE SPAN B

POTENTIAL DATA FOR 1984

DATA VALUE EXTREMES ARE 0.05 0.39

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	0.20	0.36
MAXIMUM	0.20	0.36	0.60

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

33.33 26.67 40.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
FREQ.	14	23	3

Figure 30. 1984 Corrosion Potential - No Membrane - Span C

DELAWARE BRIDGE SPAN C

POTENTIAL DATA FOR 1984

DATA VALUE EXTREMES ARE 0.06 0.52

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	0.20	0.36
MAXIMUM	0.20	0.36	0.60

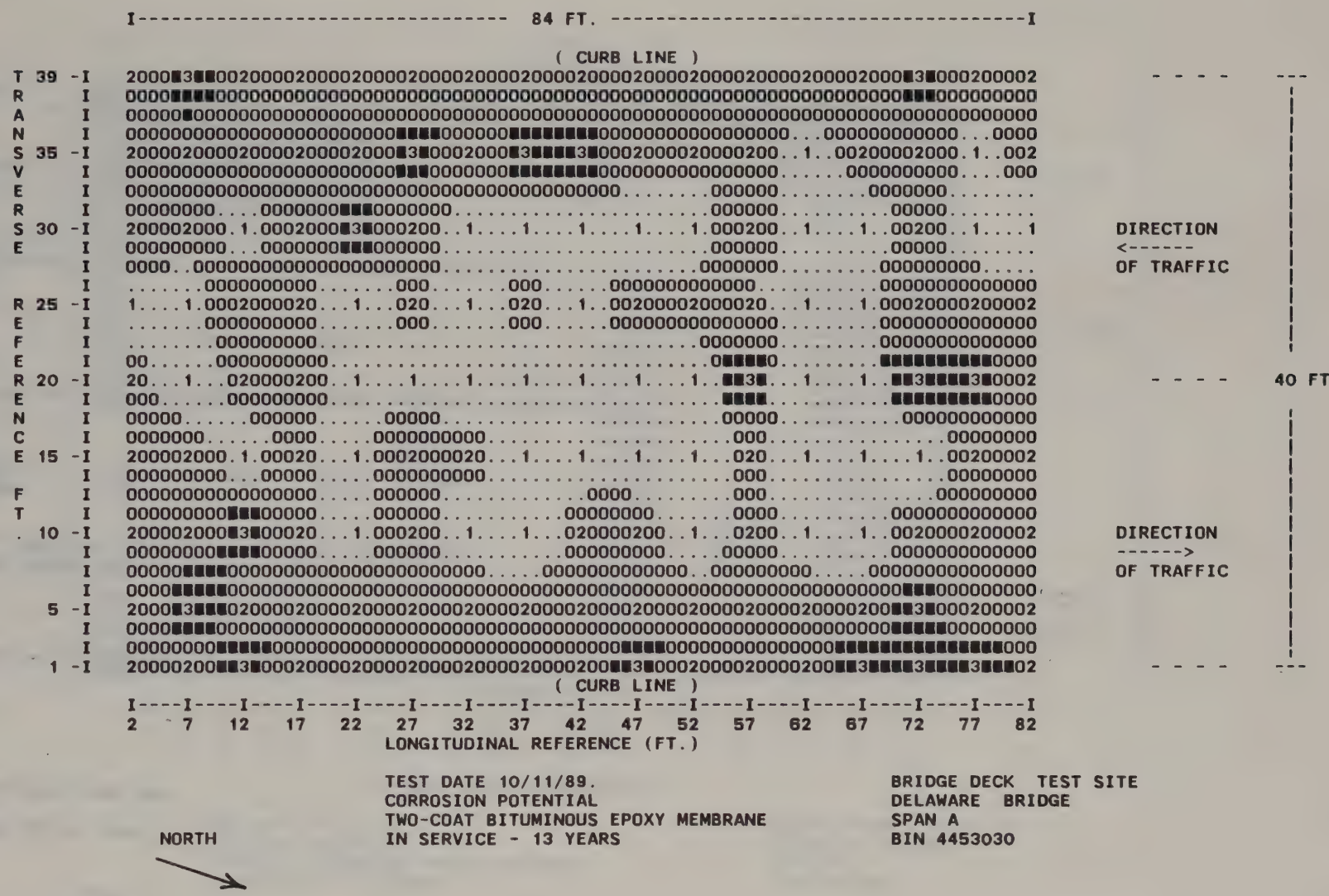
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

	33.33	26.67	40.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
FREQ.	36	34	22

Figure 31. 1989 Corrosion Potential - 2 Coat Bituminous Epoxy - Span A



DELAWARE BRIDGE SPAN A

POTENTIAL DATA FOR 1989

DATA VALUE EXTREMES ARE 0.06 0.47

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	0.20	0.36
MAXIMUM	0.20	0.36	0.60

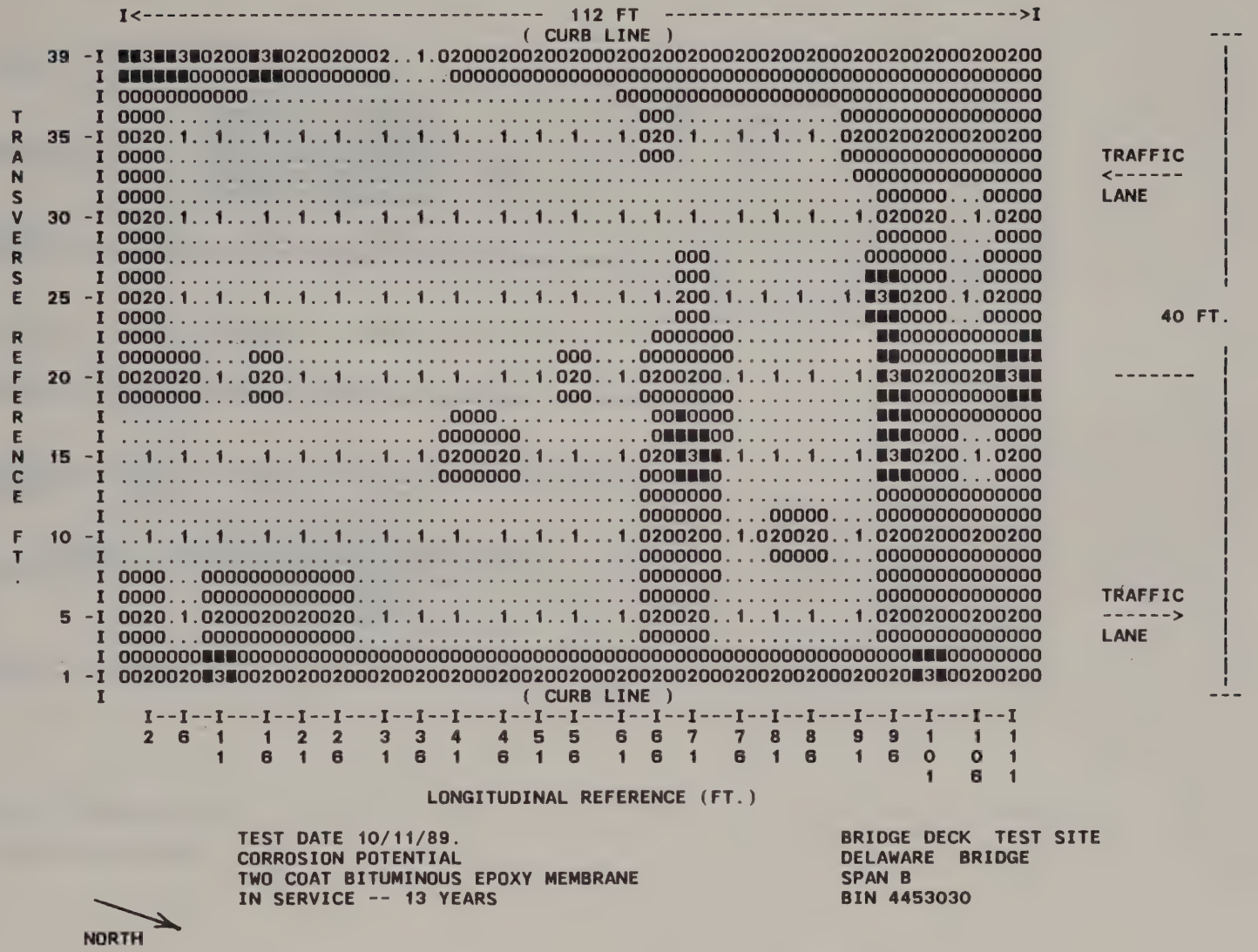
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

33.33 26.67 40.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
FREQ.	44	92	17

Figure 32. 1989 Corrosion Potential - 2 Coat Bituminous Epoxy - Span B



DELAWARE BRIDGE SPAN B

POTENTIAL DATA FOR 1989

DATA VALUE EXTREMES ARE 0.00 0.48

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	0.20	0.36
MAXIMUM	0.20	0.36	0.60

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

33.33 26.67 40.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
	==========	==========	==========
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
SYMBOLS	....1....	000020000	■■■■3■■■■
	.....	000000000	■■■■■■■■■
	.....	000000000	■■■■■■■■■
	==========	==========	==========
FREQ.	110	87	10

DELAWARE BRIDGE SPAN C

POTENTIAL DATA FOR 1989

DATA VALUE EXTREMES ARE 0.04 0.58

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	0.20	0.36
MAXIMUM	0.20	0.36	0.60

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

	33.33	26.67	40.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
		000000000 ■■■■■■■■■	
		000000000 ■■■■■■■■■	
SYMBOLS	....1....	000020000 ■■■■3■■■■	
		000000000 ■■■■■■■■■	
		000000000 ■■■■■■■■■	
FREQ.	55	62	90

Figure 33. 1989 Corrosion Potential - No Membrane - Span C